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VOL. LII.

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BENNETT H. BROUGH

SECRETARY

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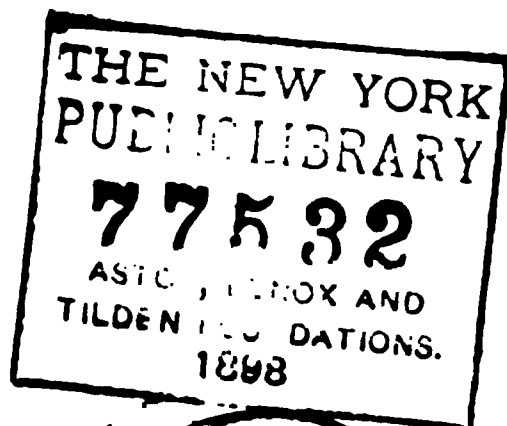
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and himself, that wherever they had been, and under however favourable circumstances they had met heretofore, in no place would they find a more cordial, hearty, and enthusiastic welcome than in that town. It was a special privilege, and he felt it to be a great honour, that he happened to be Mayor and Chief Magistrate of the town on the occasion of their visit; and bearing in mind his pleasant recollections of being with them in London in May last, and also attending the dinner at the Hotel Cecil on that occasion, he was specially proud now to welcome them to the little town (compared with London) of Cardiff. He was sure they would need no words of his to make them feel comfortable in relation both to the reception they would have in a general sense, to the hospitality that would be shown to them, and the consideration they would receive while they were engaged in the meetings during the week. They had only to read the local papers, and to see set out in detail the programme of the week's proceedings, and to reckon up the number of lunches, dinners, suppers, &c., &c., in order, as far as those "good creatures" went, to insure satisfaction to every member of the Iron and Steel Institute. But that perhaps was more humorous than anything else. What he wanted to say more especially was that Cardiff looked upon the Iron and Steel Institute as a great and mighty Institution, not only achieving noble objects in connection with its own technical workings, but spreading the benefits of its science and its knowledge throughout the length and breadth of the country and the entire civilised world. When a body of gentlemen such as he saw before him that morning could come to Cardiff and devote the whole week to the furtherance of commerce and commercial enterprise in connection with coal, iron, and steel, he thought it spoke well for the country, and he was sure they ought to and must feel deeply indebted to the members of the Iron and Steel Institute for selecting Cardiff in which to hold their annual meeting.

In another place a few moments before he had spoken to the President, and tried to impress upon his mind the fact that they were very much indebted to him and to some few others—but mainly, perhaps, to the President—for the selection of Cardiff. He wished to give the President that credit, and to assure him and



tons ; while New York stood third on the list. Some one had called Cardiff the Chicago of the West, and their hope was that it might continue to increase and prosper in the future as it had done in the past. Again he thanked the Mayor on behalf of the Iron and Steel Institute for the kind and gracious welcome that had been accorded to them, and trusted that the clerk of the weather might prove as gracious, and so enable them to enjoy the great hospitality that had been offered to them.

Sir WILLIAM THOMAS LEWIS, Bart., as chairman of the Local Committee, begged leave to thank the Mayor most sincerely for his kindness in attending and so cordially welcoming the members of the Iron and Steel Institute.

The MAYOR OF CARDIFF said he was exceedingly obliged for the very kind words that had fallen from the lips of the President and Sir William Thomas Lewis in connection with himself. He could only repeat what he had said before, that it afforded him the greatest pleasure to welcome the members in the manner he had done in the name of the town and Corporation of Cardiff. The President had referred to the position of Cardiff as a port, and perhaps he might be allowed to remind the members that the port of Cardiff exported about sixteen million tons of coal a year. It was not, therefore, so small a place as he was sorry to say some people seemed to think. Even the press were getting enlightened in relation to the great importance of Cardiff. It took them a long time to wake up, but they were now pretty much alive to the fact that the town was of "considerable importance." With the aid of the Iron and Steel Institute in connection with the present meetings, and in connection with its general work and operations, he was sure the town would soon become of still greater importance. He thanked the Institute very heartily, and hoped to have the pleasure and honour of seeing the members at the Mayoress's and his own reception, to which they had all received invitations.

The SECRETARY read the minutes of the last meeting, which were confirmed and signed by the President.



members to nominate candidates for office up to one month previous to the general meeting.

Mr. T. ASHBURY and Mr. A. P. HEAD were appointed Scrutineers, and on the completion of their scrutiny reported that the following gentlemen had been duly elected members of the Institute:—

NAME.	ADDRESS.	PROPOSERS.
Andrews, Thomas . .	Chelmsford, Newport Road, Cardiff	Thomas Morel, Edw. P. Martin, Samuel Gething Lewis.
Bailey, Thomas Henry, M. Inst. C.E.	98 St. Mary Street, Cardiff	Sir William T. Lewis, Arthur Keen, Edw. P. Martin.
Bannister, Alfred . .	Kirkstall Forge, Leeds	Arthur Cooper, Edmund Butler, B. F. Butler.
Bertrand, Ernst . .	Eisenwerk, Kladno, Austria	Karl Wittgenstein, Arthur Cooper, Percy C. Gilchrist.
Bird, Clarence . . .	2 Laurence Pountney Hill, London, E.C.	E. Windsor Richards, Berkeley Paget, James J. Wallis.
Blackwell, George Grove	The Albany, Liverpool	F. Monks, Jacob Higson, John Pattinson.
Blenkinsop, George Henry	Melbourne Place, Swansea	W. H. Powell, William Darby, Isaac Butler.
Bonvillain, Philibert .	6 Rue Blanche, Paris	A. Tannett Walker, J. Rositer Hoyle, Alexander Anderson.
Booth, Arthur . . .	Union Foundry and Iron Works, Rodley, Leeds	John Wm. Booth, A. T. Walker, T. P. Reay.
Brown, William Paterson	Bay View, Millom, Cumberland	John Crum, William McCowan, George J. Snelus.
Campbell, James . .	Iron Works, Millom, Cumberland	John Crum, William McCowan, George J. Snelus.
Chandler, Lincoln . .	Patent Shaft and Axletree Company, Ltd., Wednesbury	Claud T. Cayley, George Flett, Enoch James.
Clarke, James Crawford	427 Glossop Road, Sheffield	Sydney J. Robinson, R. A. Hadfield, Joseph S. Beckett.
Cottam, Edwin . . .	Bute Steel and Spring Works, East Moors, Cardiff	Edw. P. Martin, J. J. Pickford, A. Bowen.
Cradock, Percy Stanley	Westfield House, Wakefield	J. E. Stead, H. Herbert Andrew, F. H. Wigham.
Darby, William . .	40 Calthorpe Road, Birmingham	J. E. Stead, Arthur Cooper, John H. Darby.
Daw, Frederic Weldon	Ebbw Vale, Mon.	W. H. Powell, Edwin Carlisle, Edward Riley.
Deacon, Maurice, M. Inst. C.E.	Sheepbridge Coal and Iron Co., Chesterfield	David Evans (Middlesbrough), A. T. Walker, W. W. Clayton.
Dixon, Walter . . .	164 St. Vincent Street, Glasgow	James Riley, T. B. Rogerson, Fred. W. Paul.





NAME.	ADDRESS.	PROPOSERS.
Stevenson, John . .	Middlesbrough	John G. Swan, Walter Johnson, William Hanson.
Truran, William . .	Sirhowy Cottage, Tredgar	D. R. Jones, T. B. Hirst, David Jenkins.
Thomas, Hubert Spence .	The Cottage, Lydbrook, Gloucestershire	Josiah T. Smith, R. Beaumont Thomas, Edw. P. Martin.
Ward, Thomas William	Fitzalan Chambers, Sheffield	Arthur Horsfield, Joseph Cook, E. Windsor Richards.
While, Arthur James	Barrow-in-Furness	William F. Egerton, J. M. While, Thomas Danks.
Wight, Robert Murray	42 Exchange, Cardiff	W. Thackray, Jun., W. W. Hood, S. Gething Lewis.
Worton, Harry . . .	Park Terrace, Merthyr Tydvil, Glamorgan- shire	William Evans (Cyfarthfa), John Paton, Christmas Evans.
Wyman, Horace Winfield	Messrs. Wyman & Gordon, Worcester, Mass., U.S.A.	Henry M. Howe, Charles H. Morgan, Jerome Wheelock.

The PRESIDENT said the next business was to proceed with the reading and discussion of the papers, and he would call upon Mr. Wrightson to read his paper on the application of travelling belts to the shipment of coal.



A door on the lower end of the hopper, of dimensions sufficient to pass the largest piece of coal, allows the tail end of the heap to run out on a slope upon the surface of the belt.

This belt, in moving forward towards the quay, draws the coal naturally and quietly down the slope through the door, filling the belt with a certain thickness of coal, which travels on to the edge of the quay.

At this point it is received by another belt which is mounted on a jib, the outer end of which can, by gearing, be lowered or raised to suit the level of the ship to be loaded.

The coal is carried along this second belt until it arrives at the end of the jib, the position of which is adjusted so as to plumb the hatchway.

At the end of the jib is suspended a vertical belt, which moves in a trunk. This belt has large trays upon every alternate plate. These, in turning round the top drum, form themselves into large hoppers, the back of the advance tray and the front of the following tray forming a hopper, with sides radiating to the centre of the top drum. Into this naturally-formed hopper the coal from the end of the jib belt is directed. As the trays clear the top drum they descend in the trunk, the coal being quietly lowered until it arrives at the level of the coal in the hold, where it discharges itself as the belt passes over the lower drum of the vertical belt.

The whole machine is self-contained upon a platform which can be moved forward and backward by the same power that drives the belts. In addition to this loading of the coal, the bulk of the trimming is effected by the machine, as the jib is arranged to slew right and left over a space equivalent to the length of the hatchway, and the vertical trunk being on a swivel joint at the end of the jib, can be deflected into a position which enables the coal to be delivered under the combings of the hatchway, thus saving a great portion of the cost of trimming, and the further breakage involved in that operation.

The belts are all driven by an engine, and the man in charge can control them, also the raising and lowering of the jib, and the racking in and out of the platform by handles and clutches placed in a convenient position.

As an alternative to the vertical belt, a large rectangular or

circular trunk or box can be suspended from the jib to receive the coal from the second belt. In this trunk a large valve is arranged at the bottom, which, on being opened, allows the coal gently to flow into the hold of the vessel at the same speed at which the top is being filled from the jib belt, thus keeping the trunk always full. This valve can be controlled by a cataract or other form of brake, and made so that after the trunk is emptied the valve rises to the top of the trunk ready to receive the next supply of coal.

*DISCUSSION.*

Mr. WRIGHTSON said that the special feature of the vertical belt was the way in which the coal was delivered, not into the side, as had been previously attempted, but into the top. As the belt turned over the upper drum, there was a natural motion of the trays, which, opening radially, formed themselves into a succession of natural hoppers, and into each hopper thus formed the coal was directed from the end of the jib belt; it was then carried down and quietly discharged as the trays turned round the lower drum. He did not propose to do more than just describe the machine as it had been erected on the staithes of the Cramlington Coal Company. They had at that colliery been so far satisfied with the work of the apparatus, that they were now making special arrangements for hoppers to supply the machine, which they had found possessed a capacity for delivering the coal much greater than the means they at present had for supply from the waggons to the belt. Perhaps Mr. Morison could give the meeting some information with regard to the way in which the machine was worked at the Cramlington Collieries.

Mr. J. MORISON said that a full-sized machine had been put up by the Cramlington Coal Company in the Northumberland Dock in the Tyne. The arrangement was so far temporary that they used an old spout to supply the machine, but the machine itself was of full size, and was the practical working machine which they had been using experimentally for some weeks. Its capacity was much greater than had been originally intended. It was designed to ship at the rate of 250 tons an hour; but it was found that so far as the mechanical arrangements of the belt were concerned, it was capable, at a very moderate speed, of taking coal away from the waggons at the rate of 400 tons an hour and upwards; in fact, he did not think that they had yet gauged its capacity in that respect. The staithes, or the gangways which brought the waggons forward, were merely temporary, and they could not supply the belts fast enough, so that they could not actually gauge the consecutive shipments; but calculating from the time taken to deal with one waggon when it was put upon



South Wales. He should be glad to hear what Mr. Morison had to say on the question of trimming, which Mr. Wrightson had made a considerable point of, because that was a very important feature in regard to the saving in breakage as well as labour. So far as his judgment went, he thought that the design was a most promising one, but before deciding whether it would work in practice, they must wait and see the results of the further experiments mentioned by Mr. Wrightson as in hand at the Cramlington staithes under Mr. Morison.

Mr. A. TANNETT WALKER, Member of Council, said he had only seen the model for about five minutes at the *Conversazione* of the Institution of Civil Engineers in London, and he did not consider himself sufficiently acquainted with it from a mechanical point of view to give any opinion as to its future utility. The great difficulty he saw in it was this: a contrivance of that kind was all very well for grain and for anything which was all of the same size. For slack or anything of equal form and size, such a contrivance would act admirably; but great, ugly lumps, such as they had in South Wales could not, he thought, be very easily dealt with. They would not be led—they would not do exactly as they were told; they first jogged this way and then jogged that way, and would be apt to put out of gear the driving belts and the gearing. The scheme appeared to be a good mechanical one, and looked very simple. He did not want to be a prophet and say that it would not answer—it was always dangerous to say that a thing would not answer—but he thought it would be very difficult to apply it to South Wales coal. He could quite understand its being used on the Tyne. The coal there was not so friable and was not of the same shape as that in South Wales. When the members had had the opportunity of visiting the Bute Docks and seeing the coal there and the mode in which it was dealt with by the Lewis and Hunter scheme, he thought they would see that although Mr. Wrightson's scheme was an admirable one, it was not really adapted to Welsh coal.

Mr. FORSTER BROWN said he thought that those who were connected with South Wales would not admit that South Wales coal was more friable than the North Country coal.





might have shale in them. It did not appear to him that the 250 tons an hour which had been mentioned was a very large quantity. But Mr. Morison had said that 400 tons per hour could be shipped by the machine, and that without any lifting or lowering or tipping of trucks or anything of that sort. That was no small thing to have been accomplished.

He did not know whether all members sufficiently appreciated the importance from a national point of view of avoiding disintegration in the handling of coal. When they remembered that the value of coal in the form of coal-dust was certainly not more than half the value of round coal, they must see the extreme importance of saving in that respect. Round coal was of high market value—8s. 6d. to 9s. per ton f.o.b., being the present price in the North of England, while small coal was not worth more than 3s. 6d. to 4s. It was easy to see that every ton of coal retained as round coal, instead of being turned into small, was a positive national benefit; and he thought that Mr. Wrightson was to be congratulated on the efforts he was making to save loss in that respect.

Mr. T. HURRY RICHES had listened with great attention to the remarks which had been made in reference to the belt method of shipping coal, and he could not help thinking that what Mr. Walker had said was highly applicable to that particular method. They had in South Wales large lumps of coal, some of them 2 or 3 feet long, and he was afraid that in cases of that kind it would be very difficult to deal with it by Mr. Wrightson's machine. Again, the shape of the coal was very different from that in the North of England. Many members were no doubt aware that the cleavage of the North Country coal was more or less cubical, while the Welsh coal was very irregular; therefore the tendency to jam in anything like a confined passage in the way suggested was very great, and he feared that some trouble would arise in consequence. Mr. Head had remarked that the tipping of 250 tons an hour was very good work. People in South Wales would hardly agree with him, because they sometimes got nearly three times that amount tipped from one tip.

When the future requirements of the district were considered, whatever appliance might be adopted, the more rapid shipment



to the bottom of the coal-bins. By means, however, of a very simple and ingenious coal-drop invented by Mr. Samuel Plimsoll—whose name is well known in connection with overloaded ships and the Plimsoll Mark which all British ships now bear—the coal is not allowed to fall at all, but by means of inclines slides down into the coal-bins. The results of the experiments he (Mr. Price Williams) carried out at King's Cross, with the sanction of the then General Manager, Mr Seymour Clarke, showed that there was a saving of a little over 1s. per ton entirely due to the saving in breakage. The South Yorkshire coal he had to deal with was more friable than South Wales coal; the destructive effects, however, resulting from allowing coal to fall at all were much greater than was generally imagined. The Great Northern Company was so satisfied with the saving from breakage obtained by means of Mr. Plimsoll's coal-drop, that they entered into an agreement with him to construct the now well-known coal-drop at York Road, King's Cross, and subsequently a lease was granted him by the Company to work these coal-drops for a period of about thirty-five years, one-half the estimated saving of 1s. per ton being allowed Mr. Plimsoll, and the Company crediting themselves with the other half.

The lease of these coal-drops only expired a few months ago, and by a curious combination of circumstances it fell to his (Mr. Price Williams's) lot to have to assess with the Company's engineer the value to Mr. Plimsoll of the plant and appliances that had to be handed over to the Railway Company. These coal-drops continue to be worked by the Great Northern Company, and the system of working is now generally adopted on the Midland and other principal railways. He was quite satisfied that in the beautiful working model exhibited by Mr. Wrightson they had all the essential requirements of a most important and effective method of shipping large quantities of coal with rapidity and a minimum amount of breakage.

Mr. Morison had spoken of 400 tons an hour being shipped, as compared with the 250 tons Mr. Wrightson had mentioned as the present amount, but of course they could not anticipate that perfection would be attained at once; it was evident, however, that, with some slight modifications, much larger quantities of



the coal in those large trucks would be placed into large bunkers, and from those bunkers coal would be led by some system or other into the holds of the vessels with little or no breakage. He also wished to direct the attention of the members to another very important question which he thought had been allowed to remain pretty much as it had been for the last fifty years. In unloading vessels carrying iron ore or coal, they were now practically dealing with them in the same manner, with tubs and shovels, as they did forty or fifty years ago. It did not much matter then with sailing vessels what the demurrage was; but in these days every hour in the case of a large steamer was of very great importance. If they could reverse Mr. Wrightson's machine, and make it available for unloading iron ore, he certainly would deserve the best thanks of the iron and steel makers.

Mr. WRIGHTSON, in reply, said he had omitted to mention one feature in his description of the machine. In order to spread the delivery of the coal, he arranged differential speeds on the belts. In the case of the Cramlington coal-shipper, he gave a speed of 40 feet per minute to the first or shore belt, 60 feet to the second or jib belt, and 80 feet to the third or vertical belt; and the result was that if any accumulation of coal took place in one part of the shore belt, when it arrived at the next belt, which was moving at a speed half as great again, the coal was spread forward, so that there was no crowding. Several speakers had alluded to the quantity of coal mentioned by him—250 tons an hour. Although he designed the machine for that delivery, the only reason was that this was all they required at the Cramlington staithes. The principle could, however, be easily extended in its application, and the quantity increased, either by increasing the velocity of the belts or their width. As a matter of fact, by a slight increase in the speed of the motor a rate of 400 tons per hour had been easily attained, and he had no hesitation in saying that he could take 800 or 1000 tons, if he were asked to do so. It was only a question of size and velocity of belts.

The power, as Mr. Walker well knew, could be easily adjusted. They would have to make the machine and the tackle a little stronger, but this was a matter of no difficulty. He thought



had referred to the question of the motive power. In the case in point, the steam-engine had been used because they had one available for this experiment, but they had all along considered that where there were more machines than one, it might be desirable to work them by electrical power, or, if more convenient, by hydraulic power. In the case of the Cramlington machine, the trays were three feet wide, two feet deep, and two feet between the trays. That was found to be an ample size for all the coal. They had a gauge which would stop any piece of extraordinary size which might be beyond the dimensions of the machine.

Mr. Price Williams had made some interesting remarks on the subject of loss by breakage. He quite agreed that coal-owners did not know what a loss it was to them to have broken coal. He believed that the way in which a buyer of coal judged of it was largely by its appearance. He admitted that it was a most difficult thing to judge of the percentage of small coal, and it could only be shown by very elaborate experiments. The method suggested by Mr. Morison of taking two cargoes, one shipped by the ordinary appliances, and the other by his (Mr. Wrightson's) machine, and then unloading and riddling the coal, was the only way of really ascertaining where the advantage lay. But upon the face of it, any one who saw the quiet way in which the coal was deposited at the bottom by his machine, would, he thought, admit, without more elaborate investigation, that the saving in breakage must be very considerable indeed.

He did not know that he had anything further to say except to allude to the President's remarks as to the size of the trucks used. The President had distinguished himself by the way in which he had tackled the subject of enlarging railway trucks in the presidential address which he had delivered at the London meeting. He had, in fact, identified his name with that subject, and it was to be hoped that he would continue to do so. They had to look very largely for their future success in trade to a decreased cost of carriage in this country; and in regard to the application of big trucks, he thought that the larger the truck used in shipping coal the better. It would not affect the question of discharging, because it was just as easy to discharge a large truck as a small one, if it was properly arranged. No doubt





## THE MANUFACTURE OF TIN-PLATES.

BY GEORGE B. HAMMOND, PENARTH.

IN accepting the invitation of your Council to prepare a paper on the manufacture of tin-plates, I am keenly alive to the difficulty of doing justice to a subject which has been so ably dealt with in the interesting papers read before the Institute by Mr. Ernest Trubshaw and by the late Mr. P. W. Flower. I venture, however, to undertake the task, as considerable progress has been made in the science and practical mode of manufacture during recent years, and, however unworthy my paper may be in itself, the subject has an important bearing on the steel trade of the country, and claims more than ordinary interest for this district in which you are now meeting, as the neighbouring town of Pontypool was the birthplace of the British tin-plate trade, about the year 1665, when, under the auspices of the Hanbury family, Mr. Andrew Yarranton made an attempt to establish the manufacture there, on knowledge obtained by him in Saxony, where the trade was at that time in a flourishing condition. Mr. Yarranton's undertaking produced but little results at the time. Other active minds were, however, apparently engaged in the same direction, for it is recorded that one William Chamberlaine took out a patent in the year 1673 for "a newe arte, mistery, or invencon of great use, &c., for plateing and tynning of iron, copper, steele, and brasse, as also for compressing and plateing of all other metalls;" which invention related to the use of certain "engines or instruments and wayes and meanes" of tinning and plating iron, &c.; and eighteen years later, in 1691, John Hemingway was granted a patent, owing to influence at the court of William and Mary, for the sole use for fourteen years of an invention for "makeing of iron plates tynned over, commonly called tynned plates."

This latter patent, though never actively used, was the cause of the industry being abandoned for a time at Pontypool, until, in the year 1720, Major John Hanbury re-started the Pontypool



tin-plate works have been established within recent years, Welsh workers have been required to instruct the native labour and to assist in the development of the art. At the present time employment is found in this country for many thousands of workpeople in the industry itself, and many thousands more in those trades which are dependent on providing the materials from which tin-plates are produced; one instance of which is the fact that more than half-a-million tons of British steel bars are annually produced for the purpose, some of our largest steel-works being partially, and in some instances wholly, employed in manufacturing this material. The expansion of the trade in this country over the last thirty years has been very marked, and the extent of it may be gathered from the following statistics, taken from the Board of Trade returns, representing the shipments to all countries of the world, and taken at intervals over the period named, but they do not include the plates produced for home consumption, nor—as regards the periods to 1895—the blackplate shipped for coating abroad:—

Year.	Weight.	Value.	Average Price.
	Tons.	£	£
1867	78,906	2,060,410	26·11
1872	118,083	3,806,973	32·24
1877	153,226	3,033,126	19·80
1882	265,039	4,642,125	17·51
1887	353,506	4,792,854	13·56
1891	448,379	7,166,655	15·98
1892	395,449	5,330,216	13·48
1893	379,172	4,991,300	13·16
1894	353,928	4,338,786	12·26
1895	366,120	4,239,193	11·58
	Blackplate }	338,346	...
	34,368 }		
1896	266,963 }	3,036,015	11·37
	Blackplate }	477,999	...
	48,405 }		

It is interesting to note in the above figures the gradually declining values of the material, and it is doubtless this which has in the past given the stimulus to the trade, and has largely added to the uses for which the material has been adapted. The largest exports were in 1891, and until that year the industry had been almost entirely confined to this country, and the American market was supplied solely from Wales; but with the introduc-



It is my intention, however, to deal with the manufacture commencing with the steel bars.

For this purpose mills are employed consisting of two pairs of rolls, the first pair for breaking or roughing down the steel bar into plate form, and the second for finishing the plates.

Two heating furnaces and two pairs of shears, to one of which is attached a doubling table and squeezer for doubling and flattening the sheets after elongation between the rolls. The rolls are made of a mixture of strong, tough, cold blast iron, cast in chills. Before being put to work the necks and bodies are turned in a lathe. After being put in position in the mills the bodies are again dressed and fitted to each other, to work even together when expanded at their work.

I may here mention that the general practice in the United States varies by employing one pair of rolls only in a mill, the operation of roughing down and finishing being performed in the same pair; or in some cases three pairs of rolls are employed for two mills, one pair doing the roughing down for the two finishing.

The furnaces are of the reverberatory type, and the bars and sheets charged on the bed of the furnace are acted on by the flame from the grate placed at the back. Defects or wasters are sometimes produced by particles of small coal and ash being carried forward from the grate or picked up from the bed of the furnace, and subsequently rolled into the surface of the sheets. In some modern works, gas-producers are employed for supplying the furnaces with fuel, and beneficial results are obtained as regards quality of plates produced and the decrease of wasters.

The workmen employed in the mills are formed of sets, consisting of a roller, doubler, furnaceman, and catcher—the roller being the head and having charge of the mill. Three sets are employed for eight hours each in a day of twenty-four hours for five days in the week, and one set on the Saturday; the mills running continuously from Monday morning till midday on Saturday. A shearer and three openers generally cut and open the work from each mill.

The operation is as follows:—The rough bars from the steel-works, of suitable gauge, varying from  $\frac{1}{4}$  to  $\frac{3}{4}$  inch thick and 7 to 10 inches in width, are cut into short lengths corresponding



A machine, for which a big future seems possible, has lately been invented by Messrs. Williams and White, for opening or separating blackplate or sheets, and the following description may be found of interest:—

The machine consists essentially of two pairs of rolls, all driven at the same circumferential speed, and placed with their axes all parallel to each other. Between the first and second pair of rolls is placed a “waved guide,” consisting of hard, smooth, chilled iron plates. These plates are firmly held at a proper distance from each other, and the “guide” formed by the two plates is firmly held in position between the two pairs of rolls, as shown in Plate I.

The action of the machine is as follows:—The packs of unopened blackplate to be opened by the machine are passed through the first pair of rolls. From these they pass through the sinuous passage of the guide-plates. After leaving the last bend or curve in the guide, the second pair of rolls seizes the plates and draws the packs through, completing the operation. After leaving the second pair of rolls the packs fall on a trolley, where they accumulate until wheeled away for the next process.

It may be explained that the individual sheets comprising the pack are held together by very thin films of oxide of iron, which forms on the surface during the working of the sheets while hot.

As the packs are forced around the curves of the waved passage, the sheets of metal and the films of iron oxide are bent to and fro. This bending to and fro is harmless as far as the metal is concerned, but it is destructive to the films of oxide, hence the cementing medium is destroyed and the sheets are separated. The separation is further assisted by the varying velocities of the individual sheets in passing around the curves of the guides. For example, the sheet next the convex face of the guide travels slower than the sheet next the concave face. This sliding is seen by simply rolling a book with pliable covers, when the leaves step back from each other at the edges and the faces all slide on each other.

This sliding and bending is the principle upon which the machine is constructed, and the principle is the same as that of the method adopted by the girls of bending the corners of the packs when opening by hand.





boxes with enclosed plates are then subjected to a mild flame in a large reverberatory furnace for eight to ten hours, and are then allowed to cool gradually, the object being to soften the plates, that they may be more easily polished in the preparation for tinning.

*Cold Rolling.*—This process consists of passing the plates one by one when cold three or four times between highly polished chilled rolls working under great pressure, and is necessary to remove any buckle or unevenness from the plate and to produce a flat, bright, polished surface for receiving the coating of tin. The plates are hardened by this process, and it is necessary to give them a second or white annealing, the plates being treated in the closed pots as before, but subjected to a milder heat. On cooling they are again soft, with a bright appearance, and are in this state called finished black plate. A second or white pickling is necessary to remove any oxide formed in the annealing processes. This process is performed in the same way as the first pickling, but the acid solution is weaker, and after the plates are removed from the swilling tanks they are kept in water until taken to the tin-pot.

*Tinning.*—In former times this process was performed by soaking the plates in the molten metal, and afterwards arranging them on edge in a rack fixed in the grease-pot to allow the surplus tin to drain off them, the thickness of the coating being determined, to some extent, by the length of time the plates remained in the hot grease. The process was very wasteful, and it was impossible by its means to obtain a uniform coating over the surface of the plates. About the year 1860 Mr. Edmund Morewood of Llanelly and Mr. John Saunders of Cookley invented machines with rolls placed in the grease-pot, to better regulate the quantity of metal, whereby an immense saving was obtained, and a superior and more evenly coated plate was produced. This method, with modifications in detail, continues to the present day.

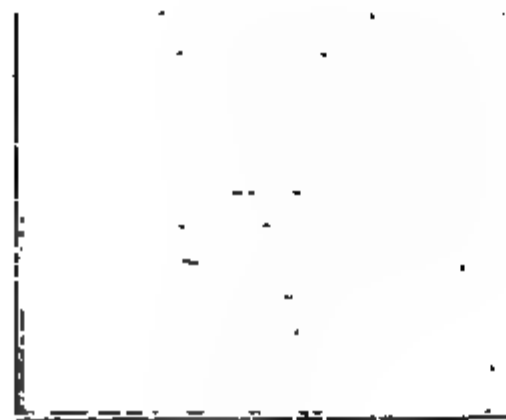
In the process as introduced by Mr. Morewood, the wet plates from the swilling-troughs of the white pickling machine were immersed, sheet by sheet, by the tinman, twenty-five to thirty at a time, in a bath of melted palm-oil to absorb the moisture on the surface of the plates, and then removed and dipped into a





















of mechanical tinning pots, by which further savings are effected in material and the services of the washman are dispensed with. These mechanical tinning pots, now known in the trade as "patents," are of various makes, the variations consisting principally in detail, each maker claiming some advantage for his machine over that of others. They may, however, be divided into two classes, in one of which the plates travel vertically, and in the other in a half-circular direction from the flux, through the tin, and into the rolls revolving in the grease-box end. Of the latter type, those of Messrs. Thomas of Melin-griffith, Daniel Edwards of Morriston, and Thomas & White of Llangennech, and of the former, those of Messrs. Taylor, Struve & Co. of Briton Ferry, and Player of Clydach are well-known machines.

Plate IV. represents a machine of the vertical type at work. This machine, patented in 1882 by Messrs. Taylor & Leyshon, and made by Messrs. Taylor, Struve & Co. of Briton Ferry, was the first single pot, for coating and finishing without the aid of the washman, to meet with practical success, and is still in use at many of the most important works to the present time, with very slight alteration in detail. The principle employed being that of drawing or pulling the plates by means of a nipping appliance working beneath the surface of the metal, through the flux into the tin in a vertical direction, so as to allow the plate to clear itself of any scruff adhering to it. The plates enter and leave the pot perfectly flat, and a coating of any quality may be produced, this being regulated by the speed of the rolls in the grease-box and by the quantity of tin in the troughs under the finishing rolls, which also tends to wash off any scruff taken up in the tin pot. The machine is simple in construction and is made of various dimensions to suit the sizes of plates to be dealt with. It is specially adapted also for thin plates or taggers, the thinnest of which can be coated by it.

Plate II. illustrates one of the "half-circular" machines. The molten tin occupies the space in the lower part of the pot, the flux lying on the surface of the tin at the feeding end, where it may be confined in position by means of a rectangular box (constructed with four sides and without ends) inserted



revolve with the object of washing or cleaning the plate of any scruff taken up from the tin pot. As the plates issue from the finishing rolls in the ordinary way they are automatically seized and removed to the rack to be dealt with by the dipper. This machine is known in the trade as the "iron man." The amount of tin required for coating by hand or by mechanical appliances is much the same. A box of  $C14 \times 20$  containing 112 sheets, and weighing 108 lbs. when finished, with a surface area of 435.5 square feet, may be coated with a good common coke finish with about 2 lbs. of tin, a heavier coating being applied for a charcoal finish. By means of the mechanical pots a saving is effected in the quantity of palm-oil used; hemp for brushes is entirely dispensed with, and a brighter plate is produced.

*Dipping and Cleaning.*—The plates on issuing from the grease-pots are either dipped by hand in fine bran, meal, or shudes, in two operations (each surface having to be treated), or are mechanically conveyed through the material placed in two troughs in such a way that both sides of the plates may be acted upon. When any grease which remained on the surface has thus been removed, the plates are rubbed by hand as previously described, or are passed through a nest of rolls covered with soft sheep-skins, which revolve at circumferential velocities varying to each other, by which the necessary rubbing is obtained, and the dust from the bran trough is removed. The operation being now complete, the plates are sorted, counted, weighed, and boxed ready for despatch from the works.

In dealing with the manufacture, no special reference has been made to terne plates, the method of their production being essentially the same as that of tin-plates, with the one exception that the coating consists of a mixture of tin and lead instead of pure tin. These plates are extensively used in the United States for roofing purposes, and it was to their production that the first efforts of the new American works were directed. The tests for tin-plates are ductility, strength, and colour, the two former properties being dependent on the quality of the steel employed and the care with which it is heated in the mill and annealing furnaces; and the latter, on the surface produced in the pickling, annealing, and cold-rolling processes, the thickness of the coating and the careful manipulation in the tinning pots.



other country, especially America, where the cost of labour was so great, would ever be able to compete with them. But the cunningness, the adaptability, and ingenuity of America succeeded in competing with England by making the consumers pay a heavy duty on all tin-plates introduced into the United States. That was undoubtedly a severe blow to this country. The statistics, so carefully prepared by Mr. Hammond, showed how the trade had increased up to 1891; the decrease had been going on ever since that period. They had, however, this little comfort. They were losing America—indeed, had lost the American trade entirely except the oil-canning trade, in which a rebate was allowed.

The Dingley Bill had practically put the last nail in their coffin so far as English tin-plates were concerned. The rebate was given in the case of plates which conveyed oil or fruit sent back to this country. But although there had been a constant decrease since 1891, chiefly due to the action of America, it was satisfactory to find that their exports to other countries had been increasing at a very rapid rate indeed. He would not enter into details, because there were other gentlemen who wished to speak on that and other subjects of interest to the Institute; but he might mention that the exports to Germany last year, as compared with the previous year, showed an increase of about 133 per cent. Although, however, the percentage of increase to other countries was large, it was a percentage on a much smaller quantity than was formerly shipped to America; hence the great difference in the returns. A short time ago he had made a calculation for the annual meeting of the Swansea Harbour Trustees, from which it appeared that if the increased shipments referred to went on at the same rate as during the last eighteen months, they would regain in eight years from the present time, if not earlier than that, the position they held in 1891.

He again congratulated Mr. Hammond on the attention he had bestowed upon his paper, which had made it so interesting to the members.

Mr. MAYBERY did not think that there was anything in the paper that needed discussion. It was a very lucid description





## PASSIVE IRON.

BY JAMES S. DE BENNEVILLE, PHILADELPHIA.

## INTRODUCTORY.

To again revive the subject of the passive state of iron—a subject which has undergone such close and exhaustive investigation for nearly a hundred and twenty years—requires some sort of explanation as to why such revival is necessary or even justified. This, however, is afforded by the rise of a new theory of the structure of iron carbides, more particularly connected with steel, which seeks to explain certain changes in the physical properties of that substance as caused by allotropic change in the iron molecule, and not by chemical combination with carbon (or other elements), or by stresses and strains set up in the mass of metal and due solely to mechanical causes. Moreover, the setting-up of this allotropic theory brings the earlier stage of the investigation into close sympathy with its latest development, and the passage from the “altered” iron of the first observers, through the “passive” iron of the earlier modern chemistry, to the theory of allotropic change—all base their explanation on a new property acquired by the iron itself, markedly different from iron in its ordinary state, only affected by external conditions, and not admitting the reagent as sharing in the change. It is proposed in the present paper to follow the history of this question as it developed itself in the researches of successive investigators; to try and trace the connection between them as showing a progressive amplification of one central idea; and finally, to touch on the factor of this question, so far subordinated to its metallic phase—viz., the condition of the reagent (acid or salt solution) in which passivity was secured.

A sharp distinction is to be drawn between true passivity—in the sense of immunity from action under conditions where ordinarily it would occur—and such cases where no chemical action ensues at a certain degree of concentration but on further dilution action does take place. To the latter are to be added



lines :—1. Chemical interference of further action of the acid—either by formation of an oxidation product which is insoluble in the acid, or a gaseous envelope; or in the case of silver solutions, by the formation of a protective coating of metallic silver, and so preventing further contact between the iron and the salt solution. 2. Mechanical interference—not derived from interaction between the acid and the metal. 3. Chemical change in the iron molecule itself—*i.e.* the iron is converted by the action of the acid, or silver salt solution, into an allotropic modification. 4. Physical change; the iron assuming a new magnetic or electric position. These four explanations do not present a direct line of experimental evidence. The earlier line of experiment was often revived—obviously from independent observation; but the particular observer of the time frequently represented in his work the accumulated experimental evidence and his final judgment as reviewer. In the frequent independence of action a general review of the subject might at this date find justification for grouping together the facts so obtained.

#### HISTORICAL.

The fact that iron was not attacked on immersion in strong nitric acid probably attracted attention at a very early date. The investigators of the iatro-chemical and earlier phlogistic period had, however, noticed the important part that water played in reactions, and the fact that nitric acid acted energetically when diluted with water clouded their ideas on the subject. Under such conditions—presence or absence of water as the important factor—Black \* refers to the reaction between nitric acid and iron, and also between sulphuric acid and iron. In fact, as late as 1861 it was claimed that hydration of the acid was the important factor, for Peretti † attributed activity to the presence of two (OH) in the acid; whereas if but one (OH) was present, no action took place. As early as 1777 Wenzel started his researches on the neutralisation of acid by metals, and the reaction between iron and nitric acid could hardly have escaped him. To

\* *Lectures*, American edition of 1806, vol. iii. pp. 168, 171.

† *Dell' azione chimica dell acqua sopra gli i sali e sopra gli acidi* (Roma, 1861), cited by Ordway.



bright ;” fuming nitric acid and strong solutions of silver nitrate “alter” iron ; such action is superficial, and removed by rubbing ; on heating, action takes place ; on diluting a silver solution, action takes place ; iron so altered does not precipitate copper from the nitrate or sulphate ; to the “two forms of iron” he gave the names “altered iron” and “fresh iron ;” when “fresh” iron is brought in contact with “altered” iron, both are acted on at first, and then action ceases ; “fresh” iron does not precipitate mixed saturated solutions of nitrate of copper and silver, or on addition of nitric acid ; the explanation of the phenomenon is to be found, not in the solution, but in the condition of the iron. Thus thoroughly Keir covered his subject, and with him is found the first idea of a change in the condition of the iron itself, the existence of an “altered” or allotropic iron.

The general subject of metallic precipitations was made an object of investigation by Vauquelin,\* Sylvester,† and more extensively by Fischer.‡ Also, in 1805, L. Thenard§ examined the action of nitric acid on iron, but mainly in reference to the formation of nitrates. In 1821 Pfaff|| examined the galvanic position of iron in a circuit with reference to a number of solutions. It was in 1827, however, that the passivity of iron was next touched upon with special reference to the abnormal property shown by the metal in its reactions with neutral and acid solutions of silver nitrate. Gustav Wetzlar¶ published the first of his papers on this subject, presenting a new side of the question, and basing his explanation of the phenomenon on an abnormal electric condition of the metal. Keir’s results had dropped out of sight, and many of the phenomena discovered by him were rediscovered by Wetzlar. He distinguished the passivity induced by silver nitrate solutions from that induced by strong nitric acid, on the ground that the former reduced copper readily from its nitrate. As the iron wire remained passive even after gentle filing or scraping, he considered that a protective coating could

\* *Allgemeines Journal der Chemie* (Scherers), 1799, vol. iii. p. 331.

† Gehlen’s *Journal der Chemie und Physik*, 1806, vol. i. p. 539.

‡ Poggendorf’s *Annalen*, 1825, vol. iv. p. 291.

§ *Annales de Chemie et Physique*, 1805, vol. lvi. p. 276.

|| Gilbert’s *Annalen der Physik*, 1821, vol. lxix. p. 84 ; Kastner, *Archiv. Naturl.*, 1827, vol. xi. p. 273.

¶ Schweigger’s *Journal der Chemie und Physik*, 1827, vol. xlix. p. 470 ; vol. l., pp. 88, 129 ; 1828, vol. liv. p. 324 ; 1829, vol. lvi. p. 207 ; 1830, vol. lviii. p. 302.



that annealed steel was not so readily attacked as hardened steel.

In 1836 Professor J. F. Daniell\* published his experiments on the material for a battery of constant electromotive force, and which resulted in the well-known copper-zinc Daniell cell. In the course of these experiments, and from "theoretical speculations on its low equivalent," he substituted wrought-iron plates for the amalgamated zincs. Although the action with such an arrangement was almost *nil*, he found that on substituting such exposed plates for the platinum pole the action was energetic. Change in the iron, as affecting its relation to hydrogen and oxygen, suggested to him an explanation of the phenomenon as due "possibly to some difference of mechanical structure developed in this particular position." The same year Professor C. T. Schönbein† wrote to Faraday, calling his attention to certain phenomena which took place when iron was immersed in strong silver nitrate solution or in strong nitric acid. Many of the data noted by Keir were again brought to light. The additions he made to the controversy were both chemical and physical—viz., oxidation as a cause of passivity; a passive wire connected *outside of the liquid* with an active dissolving wire itself becomes active. Such action he attributed to the conversion of electrical energy, transmitted in the form of a current, into chemical energy; on making the iron the positive electrode, if it be used to close the circuit, the iron is not attacked; the influence of the aqueous solution on the evolution of oxygen at the positive iron. While granting the evident effect of superficial oxidation on the passivity of the iron, Schönbein prefers as an explanation the coexistence of an electrical state different from that of the normal metal. In transmitting this letter to Mr. Phillips, at that time editor of the *Philosophical Magazine*, Mr. Faraday‡ added a number of observations of his own. These were mainly devoted to establishing the electrical position of the iron so affected; and he called attention to the fact that on immersion at first the position of the iron was electro-negative,

\* *Philosophical Transactions*, 1836, vol. cxxvi. p. 114.

† *London and Edinburgh Philosophical Magazine*, 1836, vol. ix. p. 53; vol. x. p. 75.

‡ See Schönbein, before cited; or Faraday's "Experimental Researches," vol. ii. pp. 234-247.





of intensity of current on passivity, such increase causing activity. In contact action he considered that activity depended on whether the electro-positive metal was oxidised by decomposition of water or of the acid itself, activity increasing with dilution. Also (1838), Professor Martens \* examined critically Schönbein's results. In 1839 Buff† showed that the degree of passivity depended on the strength of acid used to bring it about, and also that passivity was destroyed by washing with water; and in 1845 Beetz,‡ reviewing the recent work on the subject, declared in favour of the oxide theory as the best explanation of the passive state of iron. At this point—although only touching the subject as a secondary object—can be mentioned E. Millon's§ work on the influence of traces of salts on solution, and Gay Lussac's criticism.

In 1859 Scheurer-Kestner || again discussed the subject in connection with the formation of nitrates of iron. The particular point he touched on was as to the effect that the extent of saturation of the solution (in reference to its content of iron salt) in connection with the concentration of the acid had on passivity. But on treating one known product with acid of varying strength he found that action or inaction was independent of this factor. The next investigators were supporters of the oxide theory. Boutmy and Chateau ¶ had noted the influence that oxidising or deoxidising substances had on the reaction and the loss of passivity by washing or rubbing, and the formation of nitrate crystals after long digestion gave support to this theory. Saint Edme \* \* at this time made the distinction between steel and wrought iron the special object of his investigation, concluding that steel was made passive more readily, and remained so under conditions in which it was destroyed in the iron, both in reference to temperature and to the presence of hyponitrous acid. Peretti (1861) has been referred to in the Introduction. In 1862 Scheurer-

\* *Bulletin de l'Academie Royale de Bruxelles*, 1838-42; and Poggendorf's *Annalen*, 1844, vol. lxi. p. 127.

† Liebig's *Annalen der Pharmacie*, vol. xxxii. pp. 1, 7; vol. xxxiv. pp. 129, 241; vol. xxxv. p. 1.

‡ Poggendorf's *Annalen*, vol. lxi. pp. 92, 234; vol. lxvii. p. 186.

§ *Comptes Rendus*, 1845, vol. xxi. p. 37.

|| *Annales de Chymie et Physique*, 1859, (3) vol. lv. p. 330.

¶ *Cosmos Revue des Sciences*, 1861, (1) vol. xix. p. 117.

\* \* *Comptes Rendus*, 1861, vol. lii. p. 930.



nature of grease. He therefore introduced a new factor into the cause of such a phenomenon as passivity, viz., "catharism—or the influence of chemically clean surfaces." If the nucleus be chemically clean, there is no apparent difference between the adhesion of the gas on such surfaces and the liquid that holds the gas in solution. Strong nitric acid is a powerful "cathariser," and making an iron wire chemically clean, the acid adheres to it with force. Formation of nitrate is prevented, because nitrates of iron contain at least six equivalents of water of crystallisation, and this is not present in the stronger acid. In 1870 L. Schönner\* attributed all electro-chemical action to galvanic connection of two metals in contact with a fluid; and in 1874 A. Renard† showed that the greater the dilution of the acid in which passivity was secured, the lower the temperature was at which action was finally brought about. He also showed that in weaker acid (1.31–1.28 specific gravity) passivity could primarily be induced by agitation and repeatedly pressing the iron against the side of the vessel. The same year (1874) P. de Regnon‡ called attention to the necessity of isolating the active and inactive parts of a wire, for passivity as a rule is to be reduced to a voltaic force carrying oxygen to iron and polarising it on the surface of the metal, and its destruction to voltaic force in the opposite direction, or to a current due to the polarisation of the oxygen, or by the absorption of the polarised gas by a body having affinity for oxygen; therefore, if the wire is not divided by an isolating medium, the acid vapours will place the upper portion in a state opposed to the passivity of the immersed portion. In 1879 and in 1880 L. Varenne§ published two papers on this subject, presenting some interesting data, and basing his explanation, as Mousson had done, on the protective action of a gaseous envelope. Noting the fact that activity could be caused, under certain conditions, by shock, by means of a magnet acting over a measured distance he determined the necessary amplitude of vibration to cause activity. Passivity he accounted for on the ground that, under all circumstances, it was

\* Poggendorf's *Annalen*, 1871. Supplementary to vol. cxliv. Abstract, *Chemical News*.

† *Comptes Rendus*, 1874, vol. lxxix. p. 159.

‡ *Ibid.*, 1874, vol. lxxix. p. 299.

§ *Ibid.*, 1879, vol. lxxxix. p. 783; 1880, vol. xc. p. 998. Ramann noted the priority of Mousson.



effect in inducing passivity in iron, and this power he attributes to the presence of nitrogen. Nitrogenised iron he found to be readily made passive.

In 1889–90 Andrews\* published his papers on the passive state of iron and steel. His experiments were directed toward determining whether passivity was a static condition, and whether the chemical composition and physical structure of the iron and steel had any influence on the passivity. The method used was the measurement, by means of a sensitive galvanometer introduced into the circuit, of the electromotive force set up. Passivity he found to be considerably modified by temperature alone. Passivity increases considerably with the strength of the nitric acid. Magnetisation he found to have slight influence on cold solutions, but this increased with rise in temperature. Magnetised steel had its transition point lowered as compared with unmagnetised steel. In general terms, rise in carbon increased the passivity, and wrought iron was generally found to be less passive than even low carbon steel. In 1891 Gautier and Charpy† again attacked the question from the chemical side. They found that iron is always attacked, no matter what concentration of acid is used. The action was either rapid with evolution of gas, or slow without evolution of gas, and this latter condition they identified with the passive state of iron. In 1896 J. B. Senderens‡ examined at length the action of aqueous solutions of silver nitrate on iron which had been subjected to varying mechanical treatment. Passivity he considered to be due to the conversion of the iron, by chemical or mechanical means, into an allotropic form. As the subject covered by his results forms part of the present paper, the discussion of them will be postponed to the succeeding sections.

\* *Proceedings of the Royal Society*, 1888–90, vol. xlviii. p. 116; 1890–91, vol. xlix. pp. 120, 481.

† *Comptes Rendus*, 1891, vol. cxii. p. 1451.

‡ *Bulletin Société Chimique de Paris*, June 5, 1896, (3) vol. xv. p. 691; (3) 1897, vol. xvii. p. 279.

TABLE I.—*Composition of the Steel—in percentages.*

Sample.	Carbon.	Silicon.	Sulphur.	Phosphorus.	Manganese.
A	0·22	0·011	0·005	...	0·36
B	0·20	0·020	0·004	0·009	0·35
C	0·24	0·012	0·004	0·012	0·37
D	0·36	0·076	...	0·014	0·40

Colour carbon (Eggertz method) in hardened samples : A = 0·132 per cent., B = 0·166 per cent., C = 0·139 per cent.

*Descriptive Notes (accompanying the samples) from Mr. Kreuzpointner.*

**SAMPLE A.**—(1) Annealed after cold-hammering; (2) cold-hammered until the piece split in two; (3) original piece before hammering; (4) hardened after cold-hammering.

**SAMPLE B.**—(1) Strained six times in the testing-machine to maximum load, then broken, then cold-hammered; (2) strained six times in the testing-machine to maximum load, then broken, then cold-hammered, then annealed; (3) hardened after cold-hammering; (4) original piece.

**SAMPLE C.**—(1) Strained in testing-machine seven times, then broken after cold-hammering; (2) strained in testing-machine seven times to maximum load, then broken after cold-hammering, then annealed; (3) strained seven times in testing-machine to maximum load, then broken after cold-hammering, then hardened.

**SAMPLE D.**—(1) Half-inch axle test-piece strained ten times to maximum load, then broken, then smashed flat cold; (2) strained ten times to maximum load, then broken, then smashed flat cold, then annealed; (3) strained ten times to maximum load, then broken, then smashed flat cold, then hardened; (4) head of axle test-piece, natural state.







TABLE IIIB.—Action of Aqueous Solutions of Silver Nitrate on Hardened Mild Steel. The Solutions previously Boiled, Cooled, and the Digestions made in Closed Flasks.

Temperature 10°–20°. Form—Massive Fragments.

No.	Sample.	Description and Condition.	Remarks.	Weight of Steel Taken.	34 Grammes per L. Strong AgNO <sub>3</sub> .		1.7 Grammes per L. Weak AgNO <sub>3</sub> .	
					Immersed.	Transposed.	Immersed.	Solution Renewed.
51	A Boiler plate	Hardened	S, marked deposit of silver W, A, and M.	7.8482	2nd Mar.	4th Mar.	...	4
52		"	S, marked deposit of silver W, A, and M.	19.8612	6th Mar.	8th Mar.	...	3
53		"	S, marked deposit of silver W, A, and M.	7.1640	6th Mar.	8th Mar.	...	3
54		"	W, A, and M.	16.4926	...	...	5th Mar.	3
55	B Boiler plate	Hardened	S, heavy deposit of silver, A, W, A, and M.	42.9615	6th April	7th April	...	2
56		"	W, A, and M.	7.2327	...	...	6th April	2
57		"	W, A, and M.	12.1462	...	...	6th April	2
58		"	S, P, W, P, as drillings.	...	3rd April	5th April	...	...
59	C Boiler plate	Hardened	S, P, W, A, and M.	11.93 –	9th April	10th April	...	2
60		"	S, P, marked deposit of silver W, A, and M.	12.40 –	9th April	10th April	...	2
61		"	W, A, and M.	18.27 –	...	...	9th April	2
62		"	W, A, and M.	54. +	...	...	10th April	2
63	D Axle steel	Hardened	W, A, and M.	24. +	...	...	10th April	2
64		"	W, A, and M.	23.5 +	...	...	10th April	2
65		"	W, A, and M.	10.3 +	...	...	10th April	2
66		"	W, A, and M.	127.2 +	...	...	10th April	2



TABLE VI.—*Specific Gravities and Electrolytic Dissociation of Solutions used.*

Nitric Acid Solution— $\mu_{\infty}=342.8$ .					Silver Nitrate Solution— $\mu_{\infty}=108$ .				
v.	c.	$\mu$ .	$\alpha$ .	Specific Gravity.	v.	c.	$\mu$ .	$\alpha$ .	Specific Gravity.
c.c.									
64.1	982.6	21.0	0.06	1.420	...	...	...	...	...
93.4	674.6	49.0	0.14	1.325	...	...	...	...	...
107.4	586.4	64.7	0.18	1.290	...	...	...	...	...
111.4	565.4	67.7	0.19	1.280	...	...	...	...	...
132.0	477.2	81.6	0.24	1.240	...	...	...	...	...
150.6	418.3	103.9	0.30	1.215	...	...	...	...	...
164.7	382.4	112.8	0.32	1.195	...	...	...	...	...
225.9	278.8	154.7	0.45	1.145	...	...	...	...	...
253.1	248.6	166.8	0.48	1.130	...	...	...	...	...
281.2	224.0	172.3	0.50	1.120	...	...	...	...	...
301.7	208.8	195.3	0.57	1.115	...	...	...	...	...
500.0	125.6	220.2	0.64	1.065	...	...	...	...	...
Litres.					Litres.				
5.0	12.5	314.4	0.92	1.006	5.0	34.0	69.9	0.65	1.027
10.0	6.26	326.8	0.95	1.003	10.0	17.0	73.2	0.68	1.013
20.0	3.13	335.5	0.98	1.0005	...	...	...	...	...
40.0	1.56	340.9	0.99	1.0000*	...	...	...	...	...
...	...	...	...	...	50.0	3.4	87.5	0.81	1.002
...	...	...	...	...	100.0	1.7	90.7	0.84	1.0001
...	...	...	...	...	200.0	0.85	91.2	0.84	1.0000*
...	...	...	...	...	400.0	0.425	99.0	0.91	1.0000*
...	...	...	...	...	800.0	0.213	99.8	0.92	1.0000*
...	...	...	...	...	1600.0	0.107	99.4	0.92	1.0000*
...	...	...	...	...	3200.0	0.054	98.5	0.91	1.0000*

v=volume. c=grammes per litre of  $\text{AgNO}_3$  or  $\text{HNO}_3$ .  $\mu$ =molecular conductivity.  
 $\alpha$ =electrolytic dissociation.

PASSIVITY AND ALLOTROPY.

If the question is as to whether allotropy is the general cause of this phenomenon of the passive state of iron, and if this term is to be used in the present discussion, then a rigid definition of the term is necessary; and as here used it is understood to mean change in physical or chemical properties, or both, of an element necessarily without qualitative change in chemical composition. Although such a definition excludes the class of isomers, it does not exclude the existence of allotropic modification of an element as present in compounds of that element. Allotropy of an element, it is generally accepted, must be limited to two directions: *first*, increase or decrease in the number of atoms in the molecule; *second*,



vity; and *fourth*, whether there can as yet be given an adequate explanation of the phenomenon known as the passive state of iron. As a matter of fact the determination of these minor questions is the means of determining the main question, viz., whether passive iron is an allotropic modification of that element. In connection with these points there were determined (1) the action of strong nitric acid—on the specific gravity and on the proportion of hydrogen obtained on solution of a known quantity of metal; (2) the action of solutions of silver nitrate as modified by heat treatment or mechanical treatment of the metal; (3) conductivity of the solutions used, as a means of their ionisation.

*Silver Nitrate Solutions and Allotropy due to Mechanical Treatment.*—Professor Senderens' results can, I think, fairly be stated as follows. Calling attention to the fact that strong aqueous solutions of silver nitrate—34 grammes of  $\text{AgNO}_3$  per litre—do not attack, at ordinary temperature, iron of any kind, he considers that previous immersion in such solutions renders iron passive when transferred to solutions of such dilution as under ordinary conditions are readily reduced by iron. On direct immersion in such dilute solutions—3·4 grammes  $\text{AgNO}_3$  per litre—annealed iron or steel is invariably attacked; but in the case of cold-worked iron the behaviour is erratic, in many cases such iron not being acted on, no matter what the dilution. The two points here to be emphasised are—(1) passivity as the invariable accompaniment of previous immersion in strong aqueous solution of silver nitrate, and (2) the action of cold-worked iron toward dilute solutions of silver nitrate, for in such cases he attributes inaction to an allotropic condition of iron. Later his researches were extended to irons and steels hardened by quenching from high temperature, and these hardened irons and steels he classes with the cold-worked metal.\*

*Analysis of Tables II., III., and III. B.*—For the examination of this question Mr. Paul Kreuzpointner, of Altoona, very kindly prepared four sets of samples from boiler plate and axle steel, in which the carbon was the only metalloid present in appreciable quantity (Table I.—Composition). Two sets of experiments were made. In Table II. the silver solutions were freely exposed to air. In Tables III. and IIIB. the cold silver solutions, pre-

\* *Bulletin Société Chimique de Paris*, 1897, (3) vol. xvii. p. 279.



in its action toward dilute solutions of silver nitrate, its action should be consistent; for in making use of the nitric acid test or the copper sulphate test the criterion selected is *consistency*. The passivity of the iron is determined by its consistent reaction to these reagents, and if the reactions do not take place the existence of a passive state in the iron is denied. But cold-worked iron clearly fails at this point. The reaction is not constant for a given sample; for example, with B 7 and 8 and A 24 and 25. If B 8 and A 25 are truly representative of the reaction of Delta iron, it is difficult to understand the action of B 7 and A 24. Marking the fact that of cold-worked samples only 13 per cent. were passive under the conditions of allotropy laid down by Professor Senderens, it is difficult to explain inaction as a specific effect of cold-work. An important distinction is to be drawn between inconstancy of strong silver nitrate solutions as inducing passivity, and the apparently similar action of dilute solutions in only occasionally remaining inactive toward cold-worked iron. There are two distinct questions here presented—*first*, how far the action of strong solutions of silver nitrate can be compared with the action of strong nitric acid, and this can well be left until the action of the acid has been discussed; *second*, dilute silver nitrate solutions as a specific reaction for "Delta" iron, for, in fact, the variation in reaction may simply be a question which comes in another form under the first question.

Holding allotropy in abeyance, let us turn to the mechanical condition of the metal and examine as to whether the same inconsistency of reaction is found there. With strong solutions of silver nitrate it can be stated in general terms that all classes of steel do not reduce metallic silver. Why then does the occasional inaction of dilute solutions occur? But, it may also be asked, Why does strong silver nitrate solution rapidly attack cast iron and ferro-manganese and yet not act on annealed or cast steel? Does annealed or cast steel present a condition of iron which, as compared with its condition in cast iron, is also to be called allotropic, and is a hypothetical Epsilon iron to be called in as the only adequate explanation? For in the difference existing between annealed steel and cast iron the evidence brought forward can on the present grounds





explanation than in that of allotropy, for which, as a specific reaction, it fails entirely.

The action of solutions of silver nitrate is more decided with hardened steels than with the same samples when annealed or cold-worked. The strong solution, as a rule, gave a decided deposit of silver, and in some cases activity proceeded to exhaustion of the silver solution. Passivity at times followed digestion with the strong solution. The action of the hardened steels gave little reason to associate them with the corresponding cold-worked samples.

*Passivity is Induced by Strong Nitric Acid.*—The essential feature of such passivity is that on transference to a dilute solution, which under ordinary conditions would attack it energetically, the iron remains unattacked. Moreover, such iron no longer precipitates copper from its sulphate or nitrate. Here one condition of allotropy is reached, viz., change in chemical properties without change in composition. It is important to determine what chemical change is effected in the iron, and what relation (if any) exists between change as caused by mechanical treatment and the allotropy caused by chemical action. One means of attacking the problem seemed to lie in the effect produced by the strong nitric acid on the specific gravities, and on the volume of hydrogen obtained from a given weight of metal. Allotropy, or change in chemical composition, could alter the specific gravity, and change in chemical composition would affect the volume of hydrogen. Passivity of iron due to a magnetic or electrical state would not cause any important change in either property. Change of volume due to allotropy, while decided in its features, is readily masked by chemical change in composition. Two factors are known in this particular case, and are to be taken into consideration: (1) solution of iron and consequent lowering of the specific gravity by too large a final divisor. Even with strong nitric acid, however, quantitative determination shows this factor to be of but little importance. But (2) increase in weight, through formation of oxide or absorption of gas by the metal, this would make the final divisor too small and hence raise the specific gravity beyond the true figure, and this factor will be found to be of great importance. The determination of the specific gravities after treatment with strong nitric acid is readily made;







The action of the salt unquestionably is not so energetic as that of the acid, and it is not to be expected. This is shown not only with strong as compared with weak solutions, but on comparing strong solution with strong solution, for the concentrated silver nitrate is not in any way to be compared with the strong nitric acid as far as their power of inducing passivity is concerned.\* Failure to cause passivity can in the case of strong solutions of silver nitrate be attributed to the same delicacy of equilibrium that exists with nitric acid near the limiting point at which under no conditions of temperature or concentration passivity can be induced. The limits of dilution for silver nitrate solutions have been determined by Professor Senderens.† With more than 5.5 grammes of  $\text{AgNO}_3$  per litre iron remains inactive, and it is only as the dilution approaches 3.4 grammes, or better, 1.7 grammes per litre, that reduction actively takes place. From the point of view just taken, the fact that dilute solutions of silver nitrate sometimes cause true passivity is of the same order as passivity caused by more dilute nitric acid. In this connection it is to be remembered that strong nitric acid, causing passivity in all classes of iron and steel, shows difference in degree in the energy of its action. For example, in passing from wrought iron to high carbon steels, and taking into consideration the mechanical treatment, and whether in rolled steel such treatment was done with hot or cold steel, it will be found that on these factors depends the electromotive force existing between two given steels.‡ To explain the inaction of cold-worked iron under these occasional instances by its mechanical condition, *i.e.* its texture, has at least the advantage over allotropy, *viz.*, that the weak solution of silver nitrate is near its point of equilibrium, and under conditions in which the result may or may not give the passive condition. Consistency in reaction does not necessarily follow near the limiting point. But, if the reaction toward the silver solution is based on the then condition of the *iron*, a specific reaction for a certain existing allotropic form of that element, then consistency is necessary.

*The Value of  $\mu$ .*—An interesting point depends on the deter-

\* This difference was noticed by Wetzlar as far back as 1827.

† *Bulletin de la Société Chimique de Paris*, 1896, vol. xv. p. 692.

‡ T. B. Andrews, *loc. cit.*, vol. xlix. p. 481.



prevents the passivity of iron. If a substance be present under such conditions that its oxidation takes place at the expense of the oxidiser, no passive state of iron can be brought about. Finally, the relative value of the physical and chemical tests of allotropy and of the condition of the system can now be stated. The violent changes brought about by the action of strong nitric acid are not to be expected with the silver nitrate solution. In the former the increase of weight due to the action of the acid entirely overshadows any change in specific gravity due to allotropy, for even in such a well-known case as that of tin there is only a change of one unit in the first decimal. In this case of allotropy of iron the physical test of change in specific gravity is of but little importance owing to secondary influences, and the tests which here must be relied on to prove the case for allotropy are the instability of the system and the change in chemical reaction without change in qualitative composition. It happens, however, that change in chemical reaction under such conditions would be the one test establishing a *prima facie* case of allotropy. It seems justifiable, therefore, to sum up the positive results of determinations of specific gravity, chemical reaction, and conductivity, as showing—(1) that chemical action takes place other than can be referred to allotropy, as is shown by increase in weight of the sample taken; (2) that chemical reaction shows that true allotropic change has taken place under conditions which it would be impossible to refer to the magnetic state or a protective coating as an explanation; and (3) that the difference between the action of strong nitric acid solutions and aqueous solutions of silver nitrate is one of degree, not of kind. The same relation accompanies their dilution.

#### PASSIVITY AND THE BETA-GAMMA IRON THEORY.

Since, therefore, the balance of chemical evidence lies in favour of the existence of an allotropic form of iron brought about by chemical reaction, it remains to consider the two modifications of iron likewise attributed to allotropic change, viz., one as brought about by physical treatment of the metal, the second as brought about by mechanical treatment of the metal. The difference between the two modifications lies not only in physical properties,









Varenne does not satisfactorily explain why limits of passivity on dilution are comparatively wide. Passivity can be maintained in solutions of 1.18 specific gravity, and activity can be brought about in solutions of 1.25 specific gravity. If then the activity is due to solution of the gaseous envelope at the proper dilution, this variation is not explained. A stronger objection lies in the action of oxidising agents which *condition* passivity. How then the presence of nitric oxide can be maintained under such conditions is difficult to understand, and, it can be added, such oxidation is advanced as evidence of the presence of NO. *Fourth*—against Tomlinson's mechanical theory can be advanced Cailletet's experiments on the effect of diminishing pressure; also action of strong nitric acid on heating, passivity induced by contact, effect of dilution of silver nitrate solutions, activity induced by shock, effect of position in the circuit on passivity. *Fifth*—the existence of a magnetic or electrical state different from the normal state of iron—advanced by Wetzlar and by Herschel, and supported by the recent experiments of Nichols and Franklin and of Andrews—does not in any way conflict with the existence of an allotropic condition of the iron. As an all-sufficient explanation, however, it can be said that the existence of such a magnetic or electrical state does not necessarily postulate change in chemical reaction as shown by using a non-oxidising electrolyte or by changing the relation of iron to oxygen in the circuit. *Sixth*—an "altered" or allotropic condition of the iron, proposed by James Keir, and by Professor Senderens in one of his interesting papers on metallic precipitations and Richter's law.

On the reaction with copper sulphate solution, and on the instability of the condition brought about by chemical treatment of the iron, must be based the evidence that the passive state of iron is due to allotropic change in the iron itself. In this paper the attempt has been made to show that previous heat treatment or mechanical treatment has not affected this reaction in the case of mild steel. Beta and Delta iron do not influence, nor can they be identified with iron "altered" by treatment with strong nitric acid. Such change in the iron includes not only allotropic change, but the formation of oxide as shown by the specific gravities and by the volume of hydrogen obtained on

solution in dilute sulphuric acid; chemical reactions, however, necessitate the presence of allotropic iron. Passivity as induced by silver nitrate solutions differs in degree only from passivity as induced by strong nitric acid. It is believed that dilute solution of silver nitrate does not afford a specific reaction for the presence of cold-worked iron, because the action of this reagent is not constant for a given sample of iron; for equivalent quantities the value  $\mu$  of the acid being much greater than with the silver nitrate solutions, such solutions are properly to be compared with acid of greater concentration. At the limit at which activity takes place with the silver solutions, the value of  $\mu$  is already approaching  $\mu_{\infty}$ , the change in the value of  $\mu$  is gradual, and the limits in which passivity is caused by the solution comparatively wide.

In conclusion, I would express my indebtedness to Mr. Paul Kreuzpointner, through whose courtesy and kindness in preparing the samples the proper material was obtained.

## CORRESPONDENCE.

Professor J. B. SENDERENS (Toulouse) wrote to say that the author's conclusions did not fundamentally differ from his own, but nevertheless there were some points on which they disagreed, and with regard to these he wished to offer some observations. In order to clear the ground for this discussion, it was very necessary to define the distinction which should be made between the inactivity and the passivity of iron. Inactive iron was that which was not attacked by certain solutions of nitric acid and of nitrate of silver; passive iron was that which, after immersion in similar solutions, had lost its power of reducing more dilute solutions. These definitions were followed in the subsequent communication.

I. *Inactive Iron*.—The experiments quoted by Mr. de Benneville, which were described in the *Bulletin de la Société Chimique de Paris*,\* were made with iron wire varying from 0.5 millimetre (pianoforte wire) to 6 millimetres in diameter, both in the annealed and in the unannealed state. The unannealed wire was known as "clair et non recuit." The wires were carefully cleaned with glass or emery paper to remove all traces of oxide. None of the pieces served for two tests, and it was no exaggeration to say that more than five hundred specimens were used. The discrepancies which occurred especially at the beginning led to numerous repetitions of the experiment in search of the explanation of the variations, and it was thought that the reason was recognised.

(a.) *Solutions of silver nitrate*.—The author agreed with the writer that at ordinary temperatures neither annealed nor unannealed specimens reduced solutions containing  $\frac{1}{10}$ th nitrate of silver or 3.4 grammes per litre. But if the dilution was increased to  $\frac{1}{20}$  or to  $\frac{1}{100}$  of silver nitrate, or 3.4 to 1.7 grammes per litre, there was a difference of behaviour between annealed and unannealed iron. The former always caused a precipitate, whilst the second was more often inactive. Later on the writer showed† that, in the case of unannealed iron, the attack nearly always

\* Vol. xv. p. 691, vol. xvii. p. 279.

† *Bulletin de la Société Chimique de Paris*, vol. xvii. p. 279.



interesting paper, the author dealt with the passivity of iron in solutions of silver nitrate and nitric acid, and the relationship between these two passivities.

(a.) *Passivity in silver nitrate solutions.*—On this point also they were not agreed. The writer, using annealed wires, had found that immersion in strong solutions nearly always induced passivity to weak solutions; but Mr. de Benneville found that that only occurred to the extent of 30 per cent. On that difference some comment was necessary. How was it that in the second table three specimens out of four remained passive, whilst in the third table all the specimens were active? That divergence could not be ascribed to the presence of air, as, by the author's own showing, the phenomena was not affected by the expulsion of air. Perhaps it might be due to the use in the second series of test-pieces which had already served in the first series of experiments. That explanation was tentatively advanced, but the difference in results was none the less singular. In addition, it would seem that the percentage itself was not beyond criticism. By multiplying the results obtained by ten, any possible error was also increased, and the conclusions would have had a firmer basis if the experiments had been increased.

The passivity of worked iron in silver nitrate solutions was nowhere mentioned by the author. Possibly it might be deduced from that that there existed an allotropic difference between annealed and worked iron. That absence of passivity was the more surprising as 13 per. cent. of the worked iron was inactive in dilute solutions even before immersion in stronger liquids. But that point was not insisted upon, as the writer himself had only experimented with annealed iron, and therefore could not bring evidence adduced from his own knowledge.

(b.) *Relation between passivity induced by nitrate of silver and by nitric acid.*—Mr. de Benneville had attempted to show that these two passivities were of the same kind, and that they only differed in amount. That was confirmed by the fact noted \* by the writer, that passivity of iron in nitric acid might be brought about by first dipping it into nitrate of silver solutions and *vice versa*. There was, however, one objection. Unannealed iron, as had been

\* *Bulletin de la Société Clinique de Paris*, vol. xv. p. 695.





## ON THE DIFFUSION OF SULPHIDES THROUGH STEEL.

By E. D. CAMPBELL, ANN ARBOR, MICHIGAN.

IN 1893 the author read a paper on the diffusion of sulphide of iron through steel, before the American Institute of Mining Engineers. In this paper\* five experiments were described, in which the rapidity with which the sulphide of iron used diffused through steel at a bright red heat was strikingly shown.

In these experiments, bars of soft steel 2·5 centimetres thick, 5 centimetres wide, and 15 centimetres long were used. The steel had the following composition: carbon, 0·17 per cent.; silicon, 0·00 per cent.; phosphorus, 0·11 per cent.; total sulphur, 0·074 per cent. The sulphide of iron used in the above experiments was a sample of the ordinary fused sulphide, used for the generation of hydrogen sulphide; it contained 20·62 per cent. of sulphur.

The first purpose of the experiments was to decide whether or not an unquestioned chemical compound could diffuse through steel at a bright red heat. The statement has been made that, because carbon will diffuse through steel at a bright red heat, the diffusing carbon must be in the condition of an element. If it were possible to get sulphide of iron to diffuse through steel, then the statement that, because carbon will diffuse, therefore the diffusing carbon is in the condition of an element, is without weight. The diffusing element may or may not be in a chemically combined form.

A brief description of two of the experiments above mentioned will suffice to show the extent to which the work was carried at that time. In one case a hole 12 millimetres in diameter and 30 millimetres deep was drilled in one edge of one of the bars above described. This hole was filled with 10 grammes of sulphide of iron, and closed by driving in a short steel plug, turned to accurately fit the hole. The bar, so prepared, was

\* *Transactions of the American Institute of Mining Engineers*, vol. xxiii. p. 621.







observed immersed in the liquid sulphide. The crucible was then drawn from the furnace, and the liquid sulphide poured into a flat iron mould. This sulphide was hard, brittle, and of a steel-grey colour, with a slight yellow tinge. The analysis of the sulphide showed the following composition:—

	Per Cent.
SiO <sub>2</sub> . . . . .	0·10
Al <sub>2</sub> O <sub>3</sub> . . . . .	1·66
Fe . . . . .	75·59
S . . . . .	22·66

Assuming the sulphur and iron to be combined as a mixture of ferrous sulphide, FeS, and sub-sulphide, Fe<sub>2</sub>S, the above would give:—

	Per Cent.
SiO <sub>2</sub> . . . . .	0·10
Al <sub>2</sub> O <sub>3</sub> . . . . .	1·66
FeS . . . . .	5·84
Fe <sub>2</sub> S . . . . .	92·41
Total . . . . .	99·91

*Experiment 2.*—A bar 5 centimetres long was prepared with two holes, equally distant from the centre and ends. Each hole was filled with 12 grammes of the above sub-sulphide, and one of them plugged. The bar was placed in the furnace upon two supports, made by wrapping small pieces of iron 2·5 centimetres long, 6 millimetres wide, and 4 millimetres thick, with platinum foil. These supports were used to prevent any oxide formed during the operation from coming in contact with the muffle bottom, and also to prevent absorption by the muffle bottom of any diffused sulphide, experiments having shown that this absorption took place to a very marked degree. The bar was heated to a bright red heat, in an oxidising atmosphere, for two hours and fifteen minutes. The sulphide in the open hole had sunk very slightly, while that in the plugged hole showed no sign of diffusion.

Experiments 1 and 2 having shown that neither normal ferrous-sulphide, FeS, nor a subsulphide, approximately Fe<sub>2</sub>S, would diffuse, we next made an oxysulphide in the following manner:—400 grammes of ordinary fused sulphide, such as is used for making hydrogen sulphide, and containing 23·6 per cent. of sulphur, was ground and intimately mixed with 13 per cent. of its weight of fine magnetic oxide of iron, Fe<sub>3</sub>O<sub>4</sub>. This



being left open, so that the diffusion could be watched as it took place. The bar was supported upon the platinum supports, the open hole being directly beneath the chimney of the muffle.

9.65 grammes of the same oxysulphide was placed in a small covered porcelain crucible, which was then placed near the bar to determine whether or not the oxysulphide lost weight by heat alone. The furnace was lighted, and the temperature of the bar raised in an oxidising atmosphere. The bar attained a dull red heat in thirty minutes, and a full red in fifty minutes. At this time the sulphide in the open hole was observed to melt, and to commence to disappear rapidly: in from ten to fifteen seconds from the time the sulphide was observed to begin diffusing, the greater part of the sulphide had diffused through the steel, leaving only a small portion adhering to the sides of the hole, and a small piece, a few millimetres in diameter, in the bottom of the hole. The heat was turned off five minutes after this time, and the bar allowed to cool. On drilling into the plugged hole, the sulphide appeared to have diffused to practically the same extent as in the open hole. A rather thin scale of oxide was found on the surface of the bar, and this, on removal and analysis, showed 0.50 per cent. sulphur. It will thus be seen that the oxysulphide had diffused through the steel, and the greater part of the sulphur been oxidised by the air at the temperature at which the operation was conducted. The results of the first experiments described in 1893 proved that when that sulphide diffused through steel there was practically no retention of the sulphur by the metal. The oxysulphide in the porcelain crucible, placed near the bar of steel, melted in the crucible, but without change in weight.

*Experiment 4.*—This was planned to demonstrate that when diffusion of the oxysulphide takes place, the diffusion extends throughout the entire length of the bar, and not merely through the thin-walled metal between the holes and the sides of the bar. A bar 10 centimetres long was used, with the hole 12 millimetres from one end. In this hole was placed 12 grammes of oxysulphide of iron, the hole being left open. At the further end of the bar, a strip of sheet asbestos, about 3 centimetres wide, was so fastened that the ends of the strip were in contact with the top and bottom of the bar for a distance of about 2 centi-





A bar 5 centimetres long was used, with two holes equally distant from the ends and centre. In one hole was placed 6 grammes of cuprous sulphide, together with 6 grammes of oxy-sulphide of iron, both being ground and mixed before introducing into the hole, which was then tightly plugged. In the parallel hole was firmly pressed 4 grammes of ignited asbestos, this hole also being plugged. The bar so prepared was raised on platinum supports, and brought in an oxidising atmosphere to a bright red heat, at which temperature it was kept for two hours. The scale, which was formed on the outside of the bar by oxidation, was much smoother and stronger than when iron alone was present. The scale was divided into three portions—that from the bottom, middle, and top of the bar weighing respectively 25, 19, and 24 grammes. On drilling into the first hole, the sulphides had apparently diffused, except for a lining of cuprous sulphide in the lower portion of the hole.

On opening the hole containing the asbestos, the latter was found to be soaked for 6–7 millimetres in depth, the lower portion of the asbestos being apparently unchanged. This altered portion of the asbestos was removed, weighed, and analysed. The bar was then weighed, and two holes drilled in it, one between the two original holes, but near the top; the drillings from these holes were mixed and analysed, to find the amount of copper retained by the bar. The distribution of the copper after the diffusion is best shown in the following table:—

	Weight. Grammes.	Per Cent. of Copper.	Weight of Contained Cu.
Bar . . . . .	400	0·026	0·106
Asbestos . . . . .	6	8·06	0·483
Top scale . . . . .	24	2·47	0·593
Middle scale . . . . .	19	1·94	0·368
Bottom scale . . . . .	25	6·91	1·730
Total . . . . .	...	...	3·280

The 1·420 grammes of copper unaccounted for in the above table as the difference between the total copper added and that recovered, undoubtedly constituted the lining in the lower portion of the hole. A determination of the per cent. of sulphur (2·92) in the scale, showed the presence of 1·990 grammes, out of 2·600



was prepared by heating pure nickel wire under the same conditions as those used in making cuprous sulphide. The metal was heated and kept in an atmosphere of sulphur until it had taken up all the sulphur with which it would combine. Several experiments proved that when nickel is heated with sulphur, and the sulphide produced kept melted in an atmosphere of sulphur, the sulphide  $\text{Ni}_4\text{S}_3$  is the result.

*Experiment 8.*—To determine whether nickel sulphide, like cuprous sulphide, could be made to diffuse by mixing it with oxysulphide of iron. The bar used was 5 centimetres long, prepared with two holes, as in Experiment 6, one filled with asbestos and plugged, the other with 6 grammes of nickel sulphide and 6 grammes of oxysulphide of iron, both ground and mixed before being placed in the hole, which was afterwards plugged. The bar, upon platinum supports, was heated in the usual manner, and kept at a bright red for two hours and fifty minutes. On drilling into the hole, practically all of the nickel sulphide seemed to have remained in it, after melting down. The scale formed on the bar was divided into two parts,—that from the lower and that from the upper part of the bar—the scale from the lower portion weighing 24 grammes, and showing 0·26 per cent. of nickel or 0·023 grammes; thus it will be seen that although there was 4·26 grammes of nickel in the nickel sulphide used, only 0·085 grammes diffused through the bar. The asbestos showed no change in appearance.

The above experiments were selected from forty diffusion tests, extending over a period of about ten months, distributed in three or four intervals during the past three years. The following possible explanation of the observed phenomena might be offered. The oxysulphide being an extremely mobile liquid at the temperature at which the experiments were performed, would readily be absorbed by any porous body. The rapidity of its absorption by the crucible, while being made, shows this. If steel is at all porous at a bright red heat, then the oxysulphide would diffuse through these pores and be drawn rapidly into any porous absorbent material, such as asbestos, or scale from the superficial oxidation of the bar. The retention of so small an amount of copper by the bar after diffusion takes place, shows that although pores may exist in the steel, their volume is extremely minute,



into small fragments by the expansion of the oxysulphide on solidifying. A clean button, weighing 1035 grammes, was obtained. On breaking open this button, the upper two-thirds was found to have a distinctly crystalline structure, many individual faces, some of them 7 millimetres in length, were perceptible, although no entire crystals could be found: 635 grammes of the distinctly crystalline oxysulphide was separated, the remaining 400 grammes being compact, and showing only slight evidence of crystalline character. Although the entire 635 grammes seemed to be homogeneous, the portion used for studying the properties was obtained by selecting pieces having one or more crystalline faces. This oxysulphide is of a steel-grey colour, with a blue tinge. The sp. gr. is 4.834. It is quite friable, grinding easily to a fine powder.

The amount of oxides, other than that of iron, was determined as follows:—A weighed sample of the oxysulphide, placed in a tared platinum dish, was dissolved in  $\text{HNO}_3$ . After solution and evaporation to dryness, the nitrates were converted to oxides by gradually heating the dish to a full red heat in a muffle furnace. From the total weight of oxides thus obtained was deducted the ferric oxide,  $\text{Fe}_2\text{O}_3$ , calculated from a volumetric determination of the iron. The analysis of the oxysulphide gave the following results:—

	Per Cent.
Oxides, other than iron . . . . .	4.22
Iron . . . . .	65.88
Sulphur . . . . .	21.30
Oxygen (by diff.) . . . . .	8.60
	<hr/> 100.00

The oxides, other than iron, consisted principally of  $\text{SiO}_2$ ,  $\text{Al}_2\text{O}_3$ , and  $\text{K}_2\text{O}$ , derived from the porcelain in which the sulphide was melted and from impurities in the precipitated  $\text{Fe}_3\text{O}_4$ .

On treatment with hot  $\text{HCl}$  (1.1) the sample goes completely into solution, except a small residue of  $\text{SiO}_2$ . All of the sulphur passes over as  $\text{H}_2\text{S}$ , as was shown by absorption of the evolved gas in potassium hydrate and subsequent determination, after oxidation, as  $\text{BaSO}_4$ . All of the iron was found by titration to exist in the solution as  $\text{FeCl}_2$ . The fact that all of the sulphur passes over as  $\text{H}_2\text{S}$ , and that all of the iron exists in the solution as  $\text{FeCl}_2$ , would prove that all of the iron must have existed in the oxy-



a pure diffusing oxysulphide, but although more than forty different sulphides were made, none was obtained which would diffuse completely, although partial diffusion was obtained in many cases. The extent to which diffusion took place, varied in these latter samples from nothing to five-sixths of the sulphide. The exact conditions, whether chemical or physical, governing the formation of the diffusing oxysulphide, have not as yet been determined, although the author hopes to continue the work later on, and to make further attempts to solve this question.

He would here acknowledge his indebtedness to his several assistants, Messrs. W. G. Wallace, Firman Thompson, E. B. Hart, and Armand Miller, for the care with which they have conducted the laboratory work in the above experiments.





## THERMO-CHEMICAL STUDY OF THE REFINING OF IRON.

By HONORÉ PONTIÈRE, PROFESSOR AT THE UNIVERSITY OF LOUVAIN.

### I. PRELIMINARY REMARKS.

THE *Journal of the Iron and Steel Institute* contains two papers on the application of thermo-chemistry to the pneumatic refining of iron, one in 1889 by Mr. Pourcel on the "Applications of Thermal Chemistry to Metallurgical Reactions," and one in 1895 by Mr. Hartley on the "Thermo-Chemistry of the Bessemer Process." The object of the present paper is to explain, as far as possible, from existing analytical and thermo-chemical data the phenomena which occur during a blow in a converter.

The author is not oblivious of the boldness of such an attempt, and distinctly disclaims any idea of rigorous exactitude. On the one hand, the present ignorance of the heats of formation of silicates deprives us of an important element in the calculation; and on the other hand, the complexity of the metal under treatment and the imperfect knowledge possessed concerning the compounds in which the different elements exist, have necessitated hypotheses which may not be altogether in accordance with facts. Thus no attempt has been made to deal with double compounds, such as silico-carbides, the double carbides of iron and manganese, &c., which are difficult to estimate, and of which the heat of formation is unknown.

Even if the conclusions arrived at in this study are in harmony with the facts, there is still some uncertainty as to the validity of the argument; and to this reservation the author would add the wish that analysis may soon give some method of determining the exact composition of pig iron, and that the tables of thermal equivalents may contain all the data necessary for dealing with this interesting question.



the largest possible amount of metal, that is,  $\text{Fe}_3\text{C}$ ,  $\text{FeSi}$ ,  $\text{Fe}_3\text{P}$ ,  $\text{FeS}$ .\*

In default of knowledge of the possible and even probable combinations of the eight constituents, excluding the free iron, it is assumed, as was stated in the opening paragraph, that the eight compounds exist in a free state in the metal, and not combined amongst themselves to form double silicides or carbides of iron and manganese, or silico-carbides of one or other of the two metals, &c. It is considered that this hypothesis will not detract in any way from the main lines of the argument nor from the conclusions drawn.

## V. ULTIMATE COMPOSITION OF THE IRON.

In the metal the greater part of the sulphur is combined with the manganese as a compound, which is much more stable than the accompanying sulphide of iron. The percentage of phosphide of manganese is negligible, as has been stated above, and the same may be said of the sulphide of manganese in the particular case under consideration, on account of the low percentage of sulphur. These two compounds need only be mentioned to show that they have not been forgotten. It will be assumed that two-thirds of the manganese is combined with the carbon and one-third with the silicon. This partition seems to be sufficiently justified by the difference of the heat of formation of the carbide and silicide.†

According to this, therefore, the metal is built up as follows:—

					Per Cent.
Carbide of manganese	.	.	$\text{MnC}_2$	$\left\{ \begin{array}{l} \text{Mn. } 1\cdot00 \\ \text{C. } 0\cdot40 \end{array} \right\}$	1·40
Silicide of manganese	.	.	$\text{Mn}_7\text{Si}_2$	$\left\{ \begin{array}{l} \text{Mn. } 0\cdot50 \\ \text{Si. } 0\cdot14 \end{array} \right\}$	0·64
Phosphide of manganese	.	.	$\text{Mn}_3\text{P}_2$	...	traces
Sulphide of manganese	.	.	$\text{MnS}$	...	traces
Carbide of iron	.	.	$\text{Fe}_3\text{C}$	$\left\{ \begin{array}{l} \text{Fe. } 43\cdot40 \\ \text{C. } 3\cdot10 \end{array} \right\}$	46·50
Silicide of iron	.	.	$\text{FeSi}$	$\left\{ \begin{array}{l} \text{Fe. } 1\cdot72 \\ \text{Si. } 0\cdot86 \end{array} \right\}$	2·58
Phosphide of iron	.	.	$\text{Fe}_3\text{P}$	$\left\{ \begin{array}{l} \text{Fe. } 7\cdot58 \\ \text{P. } 1\cdot40 \end{array} \right\}$	8·98
Sulphide of iron	.	.	$\text{FeS}$	...	traces
Free iron	.	.	$\text{Fe}$	...	39·90
Total					100·00

\* If these formulæ are probable, the combination of their elements does not correspond with the same chemical compounds. This follows from the before-mentioned investigations of Troost and Hautefeuille.

† Troost and Hautefeuille, *loc. cit.*



bustion of the elements if supposed to be in a free state. The admitted heats of combustion are therefore as follows :—

	Calories.
Carbide of manganese . . . . .	116·0
Phosphide of manganese . . . . .	72·3
Sulphide of manganese . . . . .	54·8
Silicide of manganese . . . . .	52·5
Phosphide of iron . . . . .	43·3

By deducting these figures from those given for the heats of combustion of the same compounds, the resulting heat of combustion of the constituents of the iron may be obtained.

VII. HEAT OF COMBUSTION OF THE CONSTITUENTS OF IRON.

Constituent.	Heat of Formation per Gramme-atom of the Metal.	Heat of Combustion of the Free Elements per Gramme-atom of the Metal.	Heat of Combustion Resulting per Gramme-atom of the Metal.
Silicide of iron . . . . .	negligible	288·2	288·2
Carbide of manganese (C burnt to CO <sub>2</sub> ) . . . . .	116·0	290·2	174·2
Phosphide of manganese . . . . .	72·3	216·8	144·5
Sulphide of iron . . . . .	negligible	138·2	138·2
Sulphide of manganese . . . . .	54·8	164·2	109·4
Silicide of manganese . . . . .	52·5	157·6	105·1
Carbide of iron (C burnt to CO <sub>2</sub> ) . . . . .	negligible	101·5	101·5
Phosphide of iron . . . . .	43·3	129·9	86·6
Carbide of iron (C burnt to CO) . . . . .	negligible	77·7	77·7
Carbide of manganese (C burnt to CO) . . . . .	116·0	153·8	37·8

The figures in the last column are the differences between those given in the first and second columns. Those appertaining to the carbide, sulphide, and silicide of iron, of which the heat of formation has not been determined, but which is somewhat negative and at the same time negligible, are in reality somewhat too low, but the difference cannot influence the results.

VIII.—ORDER OF DISAPPEARANCE OF THE CONSTITUENTS DURING THE BLOW.

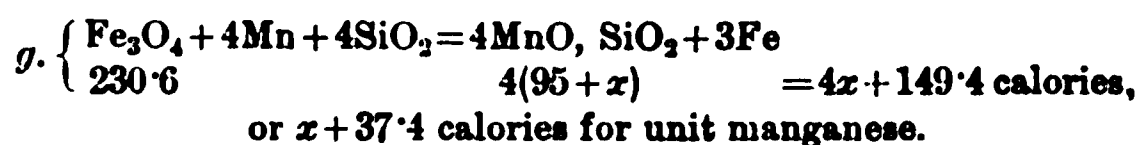
At this point it is necessary to refer to the well-known de-oxidising, carburising, and superheating effects that carbide of manganese \* adds to the end of the operation, and to seek for its

\* The superheating of the bath, which has been found by Le Chatelier to be about 60° C., is especially noticeable when the additions are made in a molten state. Cold ferro-manganese requires for melting it an amount of heat equal or superior to that disengaged or arising from the reactions of the elements.



ference of the ferrous oxide into the slag, is not to be feared as regards the protoxide of manganese formed.

It should be noted, when the additions contain free manganese, that the iron may be reduced to the metallic state, as is shown by the following thermal equation:—



Whatever the value of  $x$  may be, the resulting calorific effect is positive and noticeable.

Probably this never occurs, even if the richest possible ferro-manganese is used, for in that case the carbon may cause the formation of  $\text{Mn}_3\text{C}$ , and, with the aid of the other metalloids, all the metal enters into a state of combination.

Now that this first point has been settled, it is important to notice that the carbon burnt at the beginning of the blow is disengaged as carbonic anhydride, and towards the end as carbon monoxide. The first gas, in fact, can only exist at the temperature reached by the bath during the slagging period. This is confirmed by analyses of the gas during different stages of the blow. It should also be remarked that the sulphur can only be absorbed by the slag as sulphur, sulphurous oxide being impossible under the heat conditions in the converter. These three points being cleared away, it is time to seek the explanation of the phenomena which occur during the blow.

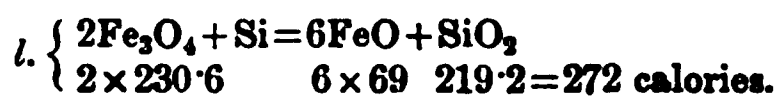
All things being equal, and excluding extraneous circumstances, the order of attack of the constituents of the metal should be given by the list of resulting heats of combustion given above. This list begins with silicide of iron and finishes with that portion of carbide of manganese from which the carbon is burnt off as carbon monoxide. As a matter of fact, the actual order is different. It is well known that the successive reactions encroach one on the other to a certain extent, and this causes the defining lines between each step to be less distinct.

The silicide of iron at the head of the list is attacked first and gives silica and magnetic oxide. But the carbide and phosphide of manganese, when their percentages are sufficiently high, in the presence of iron or under the oxidising condition of a bath traversed by air under pressure, can reduce not only oxide of





The silicon burns at the expense of the magnetic oxide, and reduces it to ferrous oxide :—

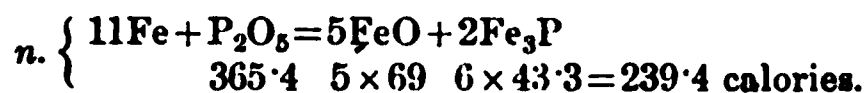
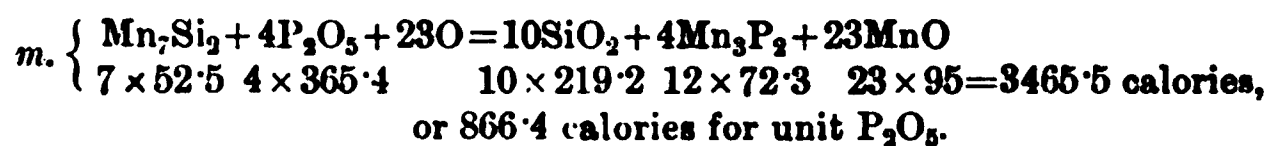


Comparison of the equations *i*, *k*, and *l* shows that the reaction *i* is only produced when there is an excess of carbide of manganese or an insufficiency of silicon. Comparison of the equations *i*, *k*, and *f* shows different results merely because the addition is made to a bath only containing combined oxygen.

This is one of the reasons why it is preferable not to turn the vessel up after an addition for a short afterblow, but to allow the reactions to take place in the turned-down converter or in the ladle.

If the manganese contents are sufficiently high, the first parts disappear at the beginning, and then the silica generated from the silicide of iron can combine with the ferrous oxide and with the manganese which has already oxidised and still continues to pursue that course.

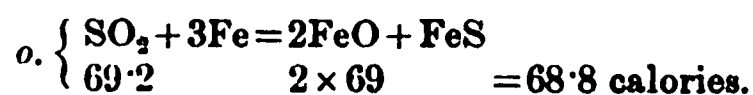
The phosphoric acid produced by the reaction *h* is reduced by the silicide of manganese and by the metallic iron :—



As the phosphate of iron only gives about 30 calories in its formation from the elements FeO and  $\text{P}_2\text{O}_5$ , the reactions *m* and *n* preferably take place.

The remaining phosphide of manganese in its turn suffers decomposition. The metallic oxides produced combine with silica, and the phosphoric acid resumes its state of phosphide of iron as the equations *m* and *n* show.

The sulphide of iron does not burn after the phosphide of manganese because sulphurous acid cannot form, being always decomposed by the heat or reduced by the iron :—

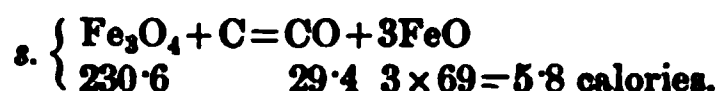


The sulphide of manganese burns subsequently ; the metallic oxide combines with silica, and the sulphur constantly returns to the state of sulphide of iron.

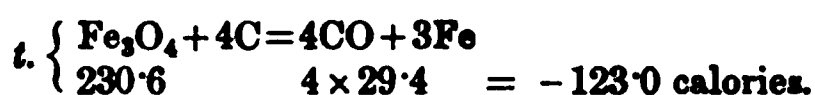


ferrous oxide and not to metallic iron. The loss of five units more in the basic than in the acid process is thus explained.

Free carbon as coke or briquettes can to a certain extent reduce the magnetic oxide—



But the reduction to iron is less probable—



By comparison of the thermal equations *f*, *s*, *t*, it will be seen that the result of the addition of free carbon is, on the whole, that it dissolves in the bath in order to bring up the metal to the required hardness.

## X. FLUCTUATIONS OF TEMPERATURE DURING THE BLOW.

The weight of the air necessary to burn off the constituents of the iron may readily be calculated, and also the weight of the products of combustion and the heat carried off by them.

Calculating from the atomic weights, a kilogramme of silicide of manganese uses up 324 grammes of oxygen, and this corresponds to 1079 grammes of nitrogen. Assuming  $1200^\circ \text{C.}$  as the temperature of the flame at the mouth of the converter, the heat carried away by 1079 grammes of nitrogen, the only gas which remains from this combustion, is  $1.079 \times 0.2438 \times 1200 = 315$  calories.

The other products of the combustion remain in the converter. The heat of combustion resulting from  $1/7 \text{ Mn}_7\text{Si}_2 = 441 \div 7 = 63$  grammes of silicide of manganese, being 105.1 calories; one kilogramme of silicide produces 1666 calories, and leaves in the converter  $1666 - 315 = 1351$  calories. The calorific efficiency is thus  $1351 \div 1666 = 0.86$ .

When the carbide of iron is burnt with the production of carbonic anhydride there is found in a similar manner—

Weight of oxygen required . . . . .	268 grammes.
Weight of nitrogen . . . . .	892 „
Heat carried off by the nitrogen . . . . .	$0.892 \times 0.2438 \times 1200 = 256$ calories.
„ „ carbonic anhydride . . . . .	$0.245 \times 0.245 \times 1200 = 71$ „
	Total . . . . . 327
Heat produced by combustion of 1 kilogramme of $\text{Fe}_3\text{C}$ . . . . .	1691
	Useful heat . . . . . 1364 calories.



The order of attack of the constituents combined with the preceding table enables the variations of temperature of the bath to be followed. At the beginning the iron is heated by the combustion of the silicon (6230 calories), the silicide of iron (2980 calories), and the carbide of manganese (1196 calories). Then the loss due to the combustion of manganese combined with phosphorus (its 127 calories being insufficient to equal the loss by radiation, volatilisation, and ejected matter) is made up for by the combustion of manganese combined with sulphur (1079 calories), and of the silicide of manganese (1351 calories), which has not been already utilised in the reduction of phosphoric acid. The combustion of part of the carbon only (3498 calories), or carbide of iron (1364 calories), accentuates the elevation of temperature.

Soon the combustion of carbon into carbonic anhydride becomes no longer possible, and it is as carbon monoxide that the larger proportion of the carbon in the carbide of iron participates in the heating effect, either as carbon burning alone (188 calories) or with the iron (1078 calories). Then the bath cools in proportion as carbon monoxide is evolved. It becomes thicker, besides which the melting point becomes higher. The blast exercises its full effect on the free iron (886 calories), giving abundant oxide, which makes the metal pasty. The remainder of the carbide of manganese reduces part of the magnetic oxide, giving off carbon monoxide according to the equation *p*. The absence of foreign bodies such as silicon and carbon, and the small amount of manganese left, causes, in default of bodies which can reduce the magnetic to ferrous oxide, the oxide of iron in the first-named state to spread itself through the metal.

The great stability of carbide of manganese as revealed by its low resulting calorific power explains why it is not attacked except indirectly in the first instance, and why highly mangiferous iron can be treated without final additions. The Swedish direct process is an application of this fact that a considerable proportion of the carbide of manganese exists until the end of the blow, and plays the part of the final additions which have to be made in the ordinary acid and basic processes.

In the basic process, the phosphorus, which at the end of the blow is entirely in the form of phosphide of iron, adds two



## XII. COMPARISON OF THE BESSEMER PROCESS WITH REFINING.

The old process of refining pig iron is comparable with the first stage of the blow in an acid-lined converter. In both processes there is the absence of basic slag and strongly oxidising atmosphere, and also the silicon is nearly the only substance eliminated. The irons formerly used in the finery contained but little manganese. None of the analyses in the author's knowledge bear upon this assertion, but it appears to be the most probable. Manganese, if it did exist to any marked extent, would have been partly removed, and the analyses agree with this.

## XIII. COMPARISON OF THE BESSEMER PROCESS WITH PUDDLING AND WITH THE PROCESSES OF BELL AND BENDER-KRUPP.

Two essential differences characterise the puddling and the Bell and Bender processes as compared with the Bessemer process. The first is that the oxygen is introduced almost entirely by the oxides of iron  $\text{Fe}_3\text{O}_4$  and  $\text{Fe}_2\text{O}_3$  contained in the slag or in the additions. The second is that the slag is abundant and basic from the start. It results from the first of these that the reaction *i* cannot take place and, since the reaction *j* gives a calorific deficit, the carbide of manganese cannot reduce the silica formed in the first instance. The silicon therefore ought always to disappear first, and the manganese follows. From the second point it results that the phosphorus may be eliminated before the carbon. Phosphide of manganese as it burns gives 144·5 calories per gramme-atom of manganese, phosphide of iron 86·6 calories, and carbide of iron only 77·7 calories when the carbon is burnt to monoxide. The difference is much more in favour of the phosphorus in that the phosphoric acid gives additional heat by its combination with oxide of iron. Altogether the dephosphorisation is not so complete as in the Thomas and Gilchrist process. The temperature is not so high on account of the fact that less heat is obtained from the formation of phosphate of iron as compared with that from phosphate of calcium. If the sulphur partly disappears in the puddling furnace, it does so before the free elimination of the carbon, for then the slag covers the metal and the reactions take place not in the body of the metal but at the clearly marked surface dividing

the two layers. The sulphides of iron and manganese, therefore, have time to dissolve partially in the basic silicate.

**XIV. TABLE SHOWING THE HEATS OF FORMATION  
USED IN THIS PAPER.**

Name.	Components.	Formula.	Molecular Weight.	Heat Disengaged.
				Calories.
Sulphurous anhydride . . .	$S + O_2$	$SO_2$	64	69·2
Phosphoric anhydride . . .	$P_2 + O_5$	$P_2O_5$	142	365·4
Silica . . . . .	$Si + O_2$	$SiO_2$	60	219·2
Carbon monoxide . . . . .	$C + O$	$CO$	28	29·4
Carbonic anhydride . . . . .	$C + O_2$	$CO_2$	44	97·6
Manganous oxide . . . . .	$Mn + O$	$MnO$	71	95·0
Ferrous oxide . . . . .	$Fe + O$	$FeO$	72	69·0
Magnetic oxide . . . . .	$Fe_3 + O_4$	$Fe_3O_4$	232	230·6
Ferrous sulphide . . . . .	$Fe + S$	$FeS$	88	24·0
Calcium sulphide . . . . .	$Ca + S$	$CaS$	72	90·8
Phosphate of calcium . . . . .	$3CaO + P_2O_5$	$3CaO, P_2O_5$	310	159·6
Phosphate of iron . . . . .	$FeO + P_2O_5$	$FeO, P_2O_5$	214	30·0

With the exception of the last number, which is adopted by Mr. Pourcel in his previously quoted work, all of them are taken from *L'Annuaire du Bureau des Longitudes* for 1897 except the figure 179·6, which is there given as the heat of formation of silica. This is a printer's error which has appeared since 1895. It is here replaced by the number 219·2 given in the previous volumes.



*DISCUSSION.*

Mr. G. J. SNELUS, Vice-President, thought all the members would admit that the paper was much too abstruse to be dealt with, as it had been, in abstract; and even if it had been read in full, he feared the members would carry away very little of its contents. He had himself read the paper somewhat carefully, but confessed that he was not able to follow all the arguments. He was a little surprised that the author had not referred to the first paper "On the Thermo-Chemistry of the Bessemer Process," written by Professor Åkerman, who was the first chemist to show how the reactions in the process produced heat. He remembered reading the paper a great many years ago. At that time it was not known that the oxidation of carbon during the process gave rise to carbonic oxide. It was always supposed that the action of the air upon the carbon in the metal gave rise entirely to carbonic acid, that all the carbon was burnt to carbonic acid; and the original calculations were based on that supposition.

While he was at Dowlais he happened to be anxious to ascertain what was really the reaction which took place during the blow, and one of his first experiments there nearly thirty years ago was to collect the gas from the Bessemer converter and analyse it, and to his great surprise he discovered that the carbon was not entirely burnt to carbonic acid. During the first half of the blow they had carbonic acid, but then the temperature rose to such an intense point that carbonic acid could not exist, and carbonic oxide was the product that was given off. He believed that those tests were the first ever made on the composition of the gases from the Bessemer converter. Having ascertained what was the composition of the gases coming off, he himself made the thermal calculation and published it in an article in "Muspratt's Chemistry as Applied to the Arts and Manufactures," published by Mackenzie. That was nearly twenty years ago. That article, he believed, explained all the reactions that took place, and it was assumed that those reactions took place in a much more simple manner than the author of the present paper



especially to the allotment by the author of the metalloids to the manganese. It was well known that at the temperature of molten pig iron the sulphur did combine with the manganese, and no doubt the other metalloids might be considerably alloyed with the manganese at that temperature. But when they came to the temperature of the solidifying of mild steel, they found the curious fact, that although the sulphide of iron, the carbide of iron, and the phosphide of iron segregated to the centre of the ingot, the manganese did not increase; this apparently indicating that at that temperature the sulphur, the phosphorus, and the carbon were not combined in any preferential manner with the manganese in the steel. It seemed to him, therefore, that the heat reactions mentioned in the paper would be to a certain extent modified by taking that view of the decomposition of the various carbides, phosphides, and sulphides during the rise of temperature of the blow.

The PRESIDENT proposed a hearty vote of thanks to Professor Ponthière for his paper, and expressed a hope that when the members had had time to study it they would communicate their views to the Secretary in writing on the subject. He thought it was a paper that should not be allowed to drop, containing, as it did, a large amount of most interesting information.

The motion was carried by acclamation.

The following paper was then read:—



The carbide was prepared by the modification of Binks and Weyl's method described by Arnold and Read.\*

The yield of  $\text{Fe}_3\text{C}$  obtained was 14·0 per cent. as against a theoretically possible yield of 14·5 per cent.

It was observed, on boiling a portion of the  $\text{Fe}_3\text{C}$  thus prepared with nitric acid of 1·20 specific gravity, that the coarser portion, *i.e.* that obtained from the cementite veins, was comparatively insoluble as compared with the fine flakes obtained from the pearly constituent.

An experiment was therefore made to ascertain if this peculiarity might be utilised to estimate quantitatively the cementite, and further to ascertain if the cementite thus separated had the same composition as the  $\text{Fe}_3\text{C}$  obtained from the pearly constituent.

A weighed portion of the  $\text{Fe}_3\text{C}$  was boiled for twenty minutes in 1·20 specific gravity nitric acid. The insoluble portion was then washed by decantation, dried with alcohol and ether, and weighed.

Assuming that the carbon in the original bar, exceeding 0·89 per cent., would exist as veins of cementite, the  $\text{Fe}_3\text{C}$  prepared from the bar (1·0 per cent. carbon) should contain 11·0 per cent. of cementite; the amount actually found was 9·8 per cent., which had the following composition:—

	Per Cent.
Carbon . . . . .	7·23
Iron . . . . .	89·90
Not accounted for . . . . .	2·87
	<hr/>
	100·00

The cementite separated was of a bronze colour and was evidently partially decomposed, as was shown by the deficiency in the analysis. The deficiency is not, however, much greater than that shown by the first batch of  $\text{Fe}_3\text{C}$ , the analysis of which (carbon, 6·92) is given later on. This experiment is therefore favourable to the supposition that the  $\text{Fe}_3\text{C}$  from the cementite and pearlite have the same composition.

In the following table are given the results of the thermal treatment of  $\text{Fe}_3\text{C}$  under varying conditions:—

\* *Journal of the Chemical Society*, 1894, p. 790.

Thermal Treatment of Tri-Basic Carbide of Iron, Fe<sub>3</sub>C.

	Wigan "Pure" Cement Bar.	Fe <sub>3</sub> C Normal.		1 Fe <sub>3</sub> C heated to about 1000° C. in and chilled in cold water.		2 Fe <sub>3</sub> C heated to about 800° C. in Atmosphere of Nitrogen.†		3 Fe <sub>3</sub> C heated to about 1000° C. in Atmosphere of Nitrogen.†		4 Fe <sub>3</sub> C fused in Magnesia in Atmosphere of CO.	
		1st Series.	2nd Series.	1st Series.	2nd Series.	1st Series.	2nd Series.	1st Series.	2nd Series.	1st Series.	2nd Series.
Silicon . . . . .	Trace.	...	...	...	...	...	...	...	...	...	...
Silica . . . . .	Nil.	0·09	...	...	...	...	...	...	...	...	...
Phosphorus . . . . .	0·008	0·004	...	...	...	...	...	...	...	...	...
Sulphur . . . . .	0·014	...	...	...	...	...	...	...	...	...	0·05
Manganese . . . . .	0·16	0·15	...	...	...	...	...	...	...	...	...
Iron . . . . .	...	91·10	91·80	...	92·6	93·4	...	93·0	92·7	...	95·40
Loss on heating in nitrogen . . . . .	...	1·48	1·35	...	...	...	...	...	...	...	...
Not accounted for . . . . .	...	1·05	0·44	...	1·05	0·23	...	0·63	0·88	...	...
Total carbon . . . . .	1·0	6·92	6·68	...	6·13	6·12	...	6·13	6·20	...	4·27
Graphitic carbon . . . . .	Trace.	0·19	0·22	...	0·56	0·40	...	2·50	2·41	...	3·05
Combined carbon (by difference) . . . . .	1·0	*5·94	*5·95	...	5·57	5·72	...	3·63	3·79	...	1·22
Combined carbon (by colour) . . . . .	...	...	...	...	...	...	...	3·58		...	...
Molecular ratio of total carbon to iron . . . . .	...	1·2·82	1·2·94	...	1·3·24	1·3·27	...	1·3·25	1·3·20	...	1·4·80
Molecular ratio of combined car- bon to iron . . . . .	...	1·3·28	1·3·31	...	1·3·55	1·3·49	...	1·5·49	1·5·25	...	1·16·61

\* Allowance made for carbon hydrate.

† The nitrogen (and argon) was prepared by passing air over heated copper and then through pyrogallate of soda solution. It was also thoroughly dried before coming in contact with the Fe<sub>3</sub>C.

The heating in No. 1 experiment occupied five minutes, the  $\text{Fe}_3\text{C}$  being enclosed in a copper tube. In Nos. 2, 3, and 4 the heating occupied half-an-hour. Nos. 2, 3, and 4 were allowed to cool down slowly *in situ*.

The second preparation of  $\text{Fe}_3\text{C}$  shows 0.44 per cent. unaccounted for, and a loss on ignition in nitrogen of 1.35 per cent., and contains practically the theoretical quantity of carbon. After ignition, all the experiments show more or less of the material unaccounted for. This probably vitiates to some extent the ratios of carbon to iron, as it seems probable that this "unaccounted-for" portion may be oxygen which has combined with the iron during the preparation of the  $\text{Fe}_3\text{C}$ .

It is interesting to note that the impurities found in the cement bar are also in the  $\text{Fe}_3\text{C}$  prepared from it, in practically the same proportions, thus showing that these impurities are disseminated equally throughout the  $\text{Fe}_3\text{C}$  and the ferrite.

Nothing peculiar was observable to the eye during the heating of the  $\text{Fe}_3\text{C}$  in nitrogen; but after allowing to cool, and removing the boat, it was found that the  $\text{Fe}_3\text{C}$  had become matted together like felt. The gases evolved during heating had a smell of hydrocarbon, which is confirmed by the loss of carbon in all cases when the carbide was heated.

It is noteworthy that in Experiments 1 and 2 very little graphitic carbon has been liberated, while in 3 and 4 increasing quantities of graphite are formed; that is to say:—

		Graphite, per Cent.
When heated to about 800° C. and slowly cooled . . . . .	little graphite } is formed }	0.40
When heated to about 1000° C. and chilled . . . . .	little graphite } is formed }	0.56
When heated to about 1000° C. and cooled slowly . . . . .	much graphite } is formed }	2.45
When fused at about 1400° C. and cooled slowly . . . . .	most graphite } is formed }	3.05

After these experiments were completed, I discovered that a somewhat similar investigation had been carried out on  $\text{Fe}_3\text{C}$  by Mylius, Foerster, and Schoene.\* These investigators state that heating  $\text{Fe}_3\text{C}$  to a red heat does not alter it, which differs from my

\* *Zeitschrift Anorg. Chem.*, 1896, vol. xiii. pp. 38–58.





CARBON AND IRON.

	Stead's Pure Wire Used.	No. 2 Button. Started with Wire.	No. 3 Button. Started with Wire.	No. 4 Button. No. 3 Remelted.	No. 5 Button. Fused Fe <sub>3</sub> C.	No. 6 Button. Started with Wire.	No. 7 Button. Grey Portion of No. 6 Remelted.	No. 8 Button. No. 7 Remelted.
Total time molten at about } 1400° C. . . . . hours }	..	2½	3½	6½	½	3	4½	5½
No. of times melted . . .	...	1	1	2	1	1	2	3
Fracture. . . . .	...	{ Grey, with white centre	{ White, very crystalline	{ Grey, with few patches of white	{ Grey	{ Grey, with white centre	{ Grey, with white centre	{ All grey
Manganese, copper. . .	Trace	...	...	...	...	...	...	...
Phosphorus . . . . .	0·014	...	...	...	...	...	...	...
Sulphur . . . . .	0·011	0·013	...	...	0·05	Nil.	Nil.	0·005
Silicon . . . . .	Trace	0·19	...	0·07	...	0·024	0·04	0·07
Iron (by difference) . .	99·975	96·31	97·97	95·94	95·43	95·93	95·13	95·19
Total carbon . . . . .	Trace	3·47	2·00	3·97	4·27	4·03	4·81	4·73
Graphitic carbon . . . .	...	...	...	...	3·05	3·00	3·84	4·03
Combined carbon (by difference)	...	...	2·00	...	1·22	1·03	0·97	0·70
Molecular ratio of total carbon } to iron . . . . . }	...	1·5·93	1·10·4	1·5·19	1·4·8	1·5·11	1·4·24	1·4·3
Molecular ratio of combined } carbon to iron . . . . }	...	...	1·10·4	...	1·16·61	1·20·14	1·21·21	1·29·56

All the buttons were allowed to cool slowly in the crucibles.  
Crucible Linings—No. 2,—10 per cent. lime; 2 per cent. calcium chloride; 88 per cent. pure lamp-black. No. 5, Magnesia (contaminated with sulphur). Nos. 3, 4, 6, 7, 8,—20 per cent. lime; 4 per cent. calcium chloride; 76 per cent. lamp-black.



Very pure iron wire, 0·04-inch in diameter, was heated to about 900° C. for varying periods in a porcelain tube full of charcoal, and at successive stages the tube was allowed to cool, and a portion of the wire removed for analysis.

The following table shows the results:—

	Pure Iron* Wire.	Same after Seven Hours' Heating.	Same after Fourteen Hours' Heating.	Same after Twenty-one Hours' Heating.
Manganese, silicon, } copper . . . . }	Trace.	...	...	...
Total carbon . . . .	Trace.	1·64	2·79	2·95
Graphitic carbon . . .	...	...	...	0·53
Combined carbon (by } difference) . . . }	...	...	...	2·42
Sulphur . . . . .	0·011	...	...	...
Phosphorus . . . . .	0·014	...	...	...
Iron (by difference) .	99·975	98·33	97·18	97·03
Molecular ratio of } total carbon to iron }	...	1:12·8	1:7·46	1:7·07
Molecular ratio of } combined carbon } to iron . . . . }	...	...	...	1:8·55

In every case the wire was allowed to cool down in the tube. It will be seen from the above figures the rate at which the carbon was absorbed by the iron, viz. :—

First seven hours . . . .	1·64 per cent. carbon absorbed.
Second seven hours . . . .	1·15    "       "       "
Third seven hours . . . .	0·16    "       "       "

As only 0·16 per cent. of carbon was absorbed in the last seven hours, it was concluded that the saturation-point had been reached at 2·95 per cent., of which amount 0·53 per cent. was in the graphitic state.

*Microscopic Examination.*—Wire of the first and second period consisted of pearlite with bands of cementite extending in all directions from side to side. The wire after the third heating, while consisting of pearlite, cementite, and graphite (which last I was unable to detect with the microscope), showed a segregation of the cementite toward the centre, none of the bands extending to the outside, thus showing a tendency to form a white nucleus

\* This wire was kindly sent to me by Mr. Stead. The analysis given is his.



and the carbon content of the remainder being ascertained. The following are the results:—

Time in Fused Calcium Chloride.	Carbon in Drillings before Treatment.	Carbon in Drillings after Treatment.	Carbon Dissolved.	Iron Dissolved.
	Per Cent.	Per Cent.	Per Cent.	Per Cent.
1 minute . . .	1·8	·52	1·33	9·72
2 minutes . . .	1·8	·11	1·71	13·31
3 minutes . . .	1·8	·09	1·72	19·00
$\frac{1}{2}$ minute . . .	1·0	·90	·16	6·29
1 minute . . .	1·0	·68	·37	6·58
$1\frac{1}{2}$ minute . . .	1·0	·51	·53	7·42

It would appear from these experiments that

(1) The cementite is dissolved bodily until a certain amount of oxide of iron is floating in the fused chloride. This is confirmed by Fig. No. 1 (Plate V.).

(2) The carbon then begins to be removed without further solution of iron. This is probably caused by the floating oxide of iron in a manner analogous to the removal of carbon by cementing with oxide of iron.

(3) As soon as the carbon is nearly all removed, the iron is again rapidly dissolved.

As will be remembered from the description of the method of etching, the process was stopped before the end of the first period, *i.e.* while both carbon and iron were being dissolved.

A series of pure steels with ascending quantities of carbon were now etched by this method. On examining them, magnified to 250 diameters, a most interesting structure was revealed, a structure which is closely identified with the percentage of carbon present.

Photo-micrographs 2 to 6 of steels containing from 1·8 to 0·10 per cent. carbon show fairly well the structure as revealed by the microscope. It should, however, be mentioned with reference to Nos. II. and III. that parts of the specimens free from cementite, or to speak more correctly, from where the cementite had been, were purposely selected, so that they may be considered as steels containing about 0·9 per cent. carbon.

It will be observed that Nos. II. and III. exhibit a very characteristic structure, which appears to consist of acicular crystals, which show a marked tendency to form triangles.



rapid chilling prevents doubt as to the structure being other than that at a bright-red heat.

Now, if the acicular structure obtained by etching with fused calcium chloride were an indication of the "adamantine allotropic modification of iron," it would be equally evident with 0·1 per cent. carbon as with 1·8 per cent. carbon, but it is entirely absent.

We therefore come to the point that at a bright-red heat iron containing 1·0 per cent. carbon has a totally different structure from iron containing 0·1 per cent. carbon, and that this difference of structure is due to the carbon *per se*.

Likewise in chilled steel we have a great difference in physical characteristics between 1·0 and 0·10 per cent. carbon, which cannot exist without the difference in carbon.

This method of investigation, while it gives no indication of an allotropic modification of iron, gives strong evidence that 0·6 per cent. carbon or upwards causes, at a bright-red heat, a radical change in the structure of iron, which must be considered as evidence in favour of the hardening of steel being due to an attenuated carbide of iron of great hardness.

Before leaving this part of my subject I should mention that, etching some steel containing small quantities of aluminium by this method, I was unable to obtain the acicular structure, which induces me to believe that aluminium, even in small quantities, may have a very marked effect on the state of the carbon in chilled steels.

Etching by fused calcium chloride might yield further information if steels were etched at carefully-regulated temperatures corresponding with the recalescence points, as I have myself obtained distinct indications of pearlite by etching at a dull red.

The following table shows the molecular ratio of carbon to iron found in the various stages of the foregoing experiments, arranged in descending order of the carbon:—





the total, we get the following corrected ratios of 1:2.90 and 1:3.04, average 1:2.97, which confirms the results of many previous observers.

We now come to the ratio 1:5, *i.e.* 4.1 per cent. carbon. E. Riley, as already mentioned, found 4.0 per cent. carbon to be the saturation point for iron by fusion. In addition to this, in two of my experiments by fusion with carbonless iron I have met with a halt in the absorption of carbon about this point, *i.e.* at 3.97 per cent. and 4.03 per cent., while  $\text{Fe}_3\text{C}$  fused expelled its carbon down to 4.27 per cent., and heating  $\text{Fe}_3\text{C}$  to  $1000^\circ\text{C}$ . in nitrogen reduced the amount of combined carbon to 3.79. The average of these results, including Riley's, give a ratio of 1:5.1, which, considering the surrounding circumstances, seems worthy of attention.

The next ratio to be considered is that of 1:7.0. The saturation of iron by cementation gives a ratio of 1:7.07. The nearness of the ratio to whole numbers is remarkable, but in the absence of confirmation by other methods it cannot be regarded, at present, as other than a coincidence.

Ratio of 1:10.4, 2.0 per cent. carbon.

In view of the hypothetical  $\text{Fe}_{10}\text{C}$  suggested by Arnold as being the formula for a carbide existing in low carbon steels outside of the pearlite, it may be interesting to mention the physical character of a metal of this composition made by fusion. It is of such a highly-crystalline nature, that, on breaking it, detached crystals drop out.

Ratio, 1:20 and 1:30.

In view of Arnold's hypothetical  $\text{Fe}_{24}\text{C}$ , it seems worth while to direct attention to the last four lines of the table, the ratios varying between 1:16 to 1:29. They are all residual combined carbon ratios after slow cooling of fairly well-saturated compounds. While, if we take the 0.60 carbon, which gives a definite acicular structure with fused calcium chloride, we get a ratio of 1:35.4, whereas 0.43 per cent. carbon specimen, which does not give a definite acicular structure, gives a ratio of 1:49.5.

A general review of the table of ratios shows that carbon combines with iron in all proportions up to 4.81 per cent., and





that iron produces on cooling a decomposition or crystallisation product having the formula of  $\text{Fe}_3\text{C}$ . There is thus no evidence sufficiently strong to indicate the formula of any other definite carbide of iron.

In conclusion, I wish to record my thanks to Messrs. Arnold, Seaman, and Stead for kindly supplying me with samples of steel, and to Mr. Stead for valuable instruction in metallo-micrography and photo-micrography.

*DISCUSSION.*

Mr. G. J. SNEBUS, Vice-President, said that the members were greatly indebted to Mr. Saniter for his very excellent, practical, and most important paper. He hailed it with great satisfaction as bringing them back to a little simplicity in regard to carbon compounds of iron. He had been almost frightened at the great number of carbon compounds which some of their friends were anxious to establish as existing in connection with iron. He thought the result of the paper went to prove that while there might be, and possibly was, one very definite compound of carbon and iron, namely,  $\text{Fe}_3\text{C}$ , probably that was the only one that existed. He had always looked upon the action of carbon in relation to iron as one of solution mainly, and he thought all the evidence went to prove that carbon was dissolved in iron up to a certain point. All his experiments quite agreed with those of Mr. Riley and Mr. Saniter, that the saturation-point of iron and carbon was certainly below 5 per cent.; and he thought it was not far from the figure which Mr. Riley had mentioned—about 4.8. While iron might only be able to dissolve carbon up to that point, it was quite possible that a definite compound might be formed between the carbon and the iron  $\text{Fe}_3\text{C}$ , and that the remainder might be simply held in that very weak state of chemical combination which was termed solution. He did not at all see how they could explain the separation of graphite from pig iron if they assumed that the whole of the carbon existed as a definite compound. He did not see what force there was to separate free carbon from the iron on the solidification of the body if it existed as a definite compound; but if it existed merely in solution, or if the bulk of it existed merely in solution, there was every reason for the ordinary action of solutions taking place, namely, that as they got colder some of those substances which they held in solution separated out.

With regard to ordinary chemical solutions, saturated with a given salt, some of them would still retain the whole of the salt solution on cooling, but a great many of them would deposit a portion on cooling. He thought that all the facts they knew in relation to iron and carbon pointed to that same action.







































The iron (ferrite) united with a certain amount of this carbide to form pearlyte, as follows :—

$$\begin{array}{ccc} \text{Fe.} & \text{Fe}_3\text{C.} & \text{Fe.} \\ 86\cdot65 & : 13\cdot35 = & 85 : x. \end{array}$$

for if pearlyte contained 0·89 per cent. of carbon, it was made up of 86·65 per cent. of ferrite and 13·35 per cent. of cementite. The equation gave very nearly 13·1 for the value of  $x$ , leaving an excess of cementite of 1·9 per cent. In round numbers, Mr. Saniter's steel was made up of 98 per cent. of pearlyte and 2 per cent. of cementite. About 13 per cent. of his residue, therefore, must be derived from the free cementite existing in the steel.

The structural composition might perhaps be calculated more rapidly as follows :—

Let  $x$  be the percentage of pearlyte,  $y$  the percentage of cementite in the steel ; then

$$x + y = 100.$$

The pearlyte would contain  $\frac{0\cdot89x}{100}$  per cent. carbon, the cementite  $\frac{6\cdot67y}{100}$  per cent. of carbon ; therefore

$$\frac{0\cdot89x}{100} + \frac{6\cdot67y}{100} = 1 \text{ (percentage of total carbon).}$$

These two equations give

$$x = 98\cdot1 \text{ and } y = 1\cdot9$$

or roughly 98 per cent. of pearlyte and 2 per cent. of cementite.

He would like to offer a few remarks regarding Mr. Saniter's microscopical investigations. In the paper it was stated that the structure made apparent by the etching was, without doubt, that existing at a bright red heat. He (Mr. Sauveur) did not see how such could be the case, for if it were so, it would be necessary to conclude that the chloride of calcium remained passive until the metal had reached the temperature of the bath, becoming passive again during the cooling. As a matter of fact, however, the metallic surface must be acted upon as soon as it came in contact with the fused chloride, and the action must continue, although possibly with varying intensity, as long as the steel remained in the salt. But as the metal was

















It was possible to elaborate many theories about iron and steel, but it was dangerous to receive them as truth without a good deal more solid basis than was at present available. Mr. Saniter's ingenious theories, like many others, would no doubt give rise to much thought and work, with results which would lead on to truth.

The PRESIDENT proposed a hearty vote of thanks to Mr. Saniter for his able and interesting paper.

The vote of thanks was carried by acclamation, and the following paper was read, in the absence of the author, by Mr. Wicksteed :—





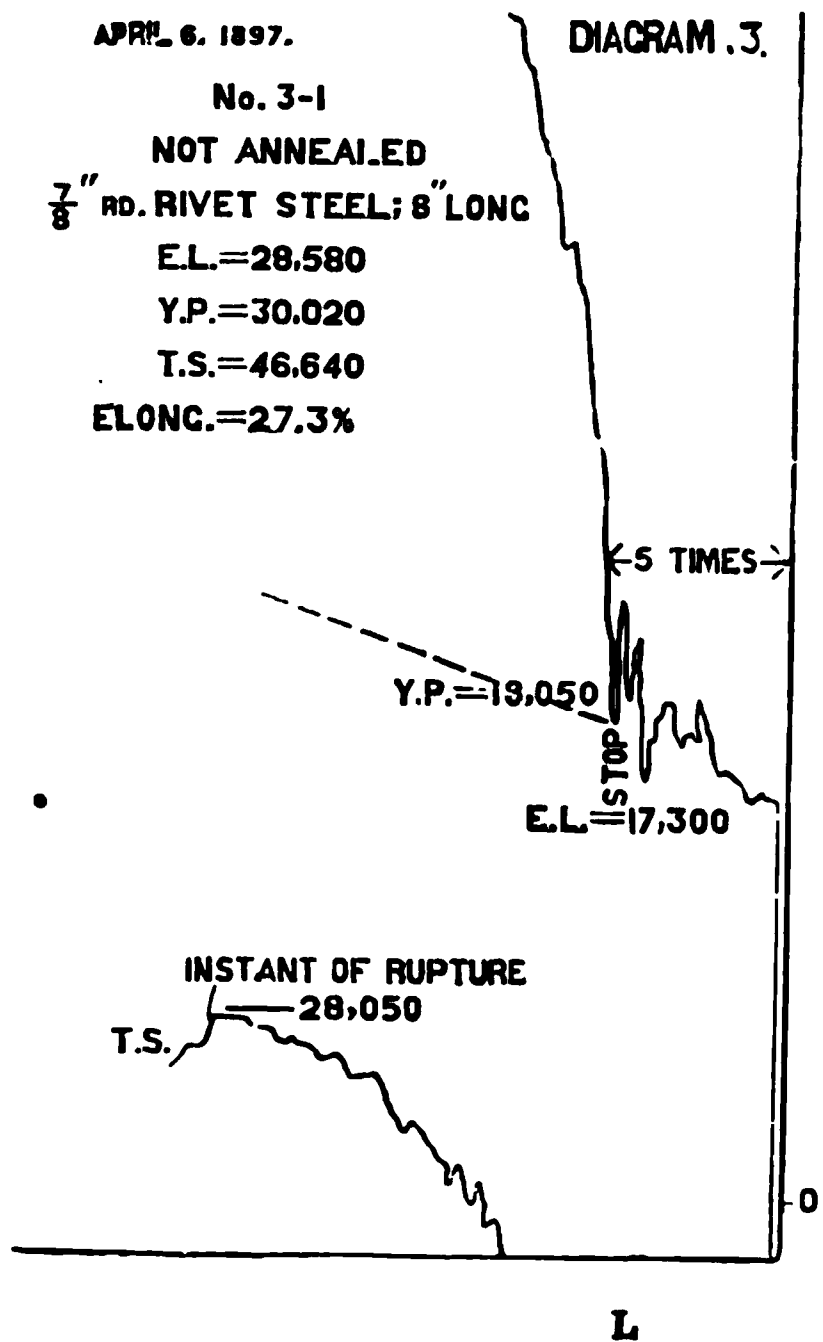
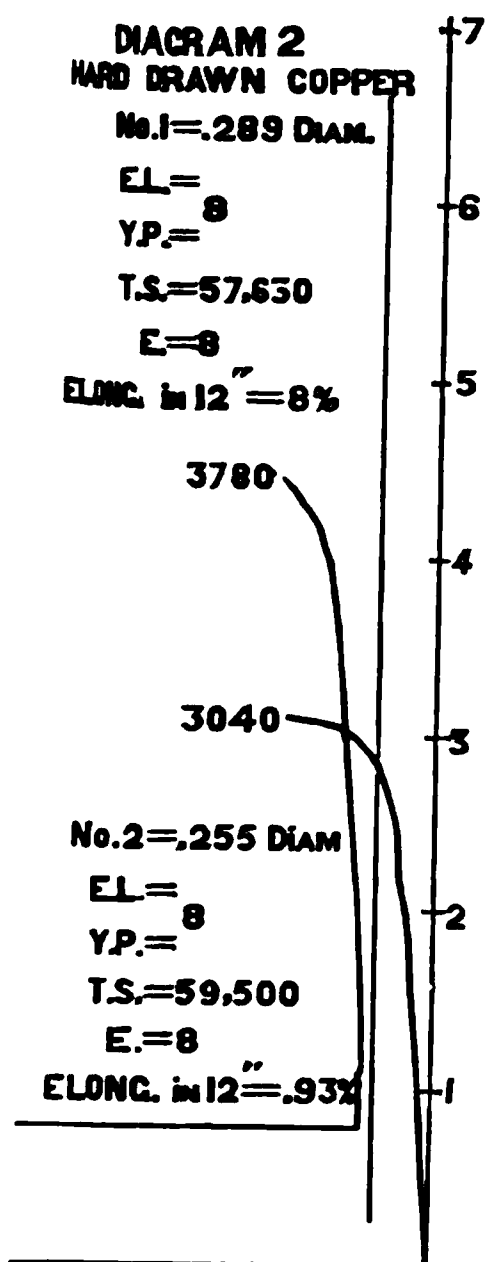
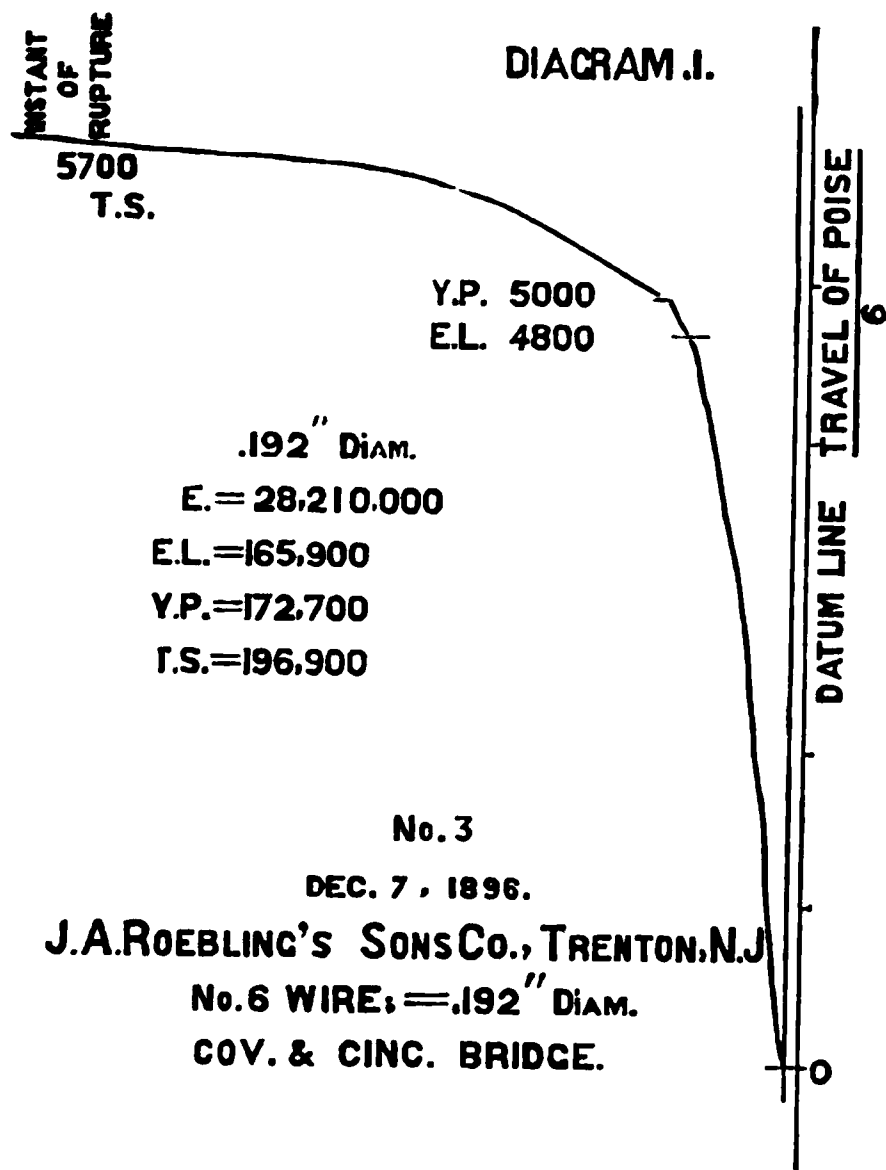


















an apparatus which, if constructed sufficiently light and accurately, yet sufficiently strong to stand the rapid work of the testing-room, would give something which many of us would like to have. The Aspinall automatic recorder is illustrated in Plate VII.

#### RECORDER ON 100 TONS TESTING MACHINE.

Fig. 1 is an end elevation of the apparatus as fixed on the testing machine.

Fig. 2 is a front elevation of the same, showing the connection to a test-piece.

A is a test-piece fixed in the machine; two clips B B<sup>1</sup> are attached to it 8 inches apart; on the bottom clip B<sup>1</sup> rests a steel rod C, with a balance weight at each end; a wire is connected from the centre of this rod to the pencil carriage D, which will cause the pencil to travel equal to the amount of extension of 8 inches of the test-piece (or the strain in 8 inches of length).

The back end of the pencil carriage D is connected by a wire to the tension pulley E.

F is the drum on which the diagram is taken, this drum being fixed on a carriage G, movable on the guide rods H; a wire is connected to the carriage G from the rod J on the top clip B.

L is a handwheel by which the stress is applied to the test-piece A; as the handwheel is revolved the motion is transmitted to the drum F by the gearing and wire.

The movement of the pencil indicates strain, and radial movement of the barrel indicates the amount of stress producing such strain.

Dr. A. C. ELLIOTT (University College, Cardiff) thought that Mr. Henning had been singularly fortunate in securing Mr. Wicksteed to present his paper, because that gave them a claim upon their attention, Mr. Wicksteed being well known as a pioneer worker in the field of automatic recording. As Mr. Henning had remarked, there were many recorders, all more or less perfect; but the question that occurred to one was, what was the primary use of a recorder? Mr. Henning apparently thought that one principal use was the determination of the yield point or the limit of elasticity point. That point was variously circumstanced in different kinds of material. Sometimes it was exceedingly sharp and well marked, and sometimes it was not at all well marked. Sometimes there was an incipient yielding or elastic failure, the straight line recording Hooke's Law running



the travel of the jockey-weight—and the diagram produced was nearly useless for the purpose in hand. He had to plot the serviceable diagram from extensometer observations, while the diagram copied from the traverse of the poise-weight was unsatisfactory, and nearly useless. A recorder that took the stress co-ordinate from the traverse of the poise-weight was certainly not better than the Wicksteed recorder, which took that co-ordinate from the pressure in the hydraulic straining cylinder, as already described.

He wished to take that opportunity of saying that he was perfectly convinced that the people who considered the friction of the cup leathers of the ram and its attachments a great thing were wrong, and that the plan he had mentioned was the only one that could be pursued with anything like a hope of getting a correct continuous record. He should not like to condemn a piece of apparatus without having seen it, far less without having tried it. Mr. Henning's recorder might be all very well, and it might turn out well, and it might be portable. He was himself speaking, mainly from experience, of a thing that he knew, and that he had well tried. It certainly was not a machine that could be put in one's pocket, but it was an engineer's tool.

Mr. HADFIELD asked what was the cost of a recorder?

Mr. WICKSTEED said it was about £25.

Mr. HADFIELD said that all who were connected with steel had now to do much more testing than at any former period, and he thought it would be a good plan if Mr. Wicksteed would allow the machine to be exhibited in London, where the members might see it; also if he would allow one to be tested at the Sheffield Technical School. Those in charge of the School were always desirous to keep the students well posted up in any advances that were made, and he should be glad if Mr. Wicksteed could get Mr. Henning to allow them to have one of the recorders there for testing purposes.

He should also be glad to know if the apparatus was suitable for testing high elastic limits. Those who were connected with the manufacture of special steels had to pay special attention to



crossways of an axle, and other items of manufacture, could be reduced to the same proportions as those of an eyebar for a Warren girder bridge or a chain cable, or a long bolt for use in a marine engine. He did not think they could always get those things in the same proportions—that was, a length of say eight diameters, or any other proportion they might choose to fix upon at a congress. He thought it was not practicable to try and establish a form of test-piece which would be the same for all nations, no matter what their unit of measurement was, and which would be of similar proportions in all cases. That brought him to say that he thought it would be entirely unnecessary to reduce test-pieces to similar proportions if only they would separate the general extension, expressed in percentage of length, from the local or breaking elongation, which had no relation to the length, and which was wrongly expressed if expressed in percentage of length. The diagram recorded the local elongation during breaking, that was, after the maximum strength of the piece had been passed; then the piece began to bottle-neck, to draw in, to contract locally and to extend locally. That extension had no relation to the length of the piece, and if a person testing a 2-inch piece credited the 2-inch piece with that local extension, he might report an increased percentage of extension of about 25 per cent. But if he had a 10-inch piece, and he credited that with this constant quantity, this local extension, he only benefited his report to the extent of 5 per cent. Hence all the discrepancies and difficulties of comparison; hence the difficulty of comparing the ductility of a small sample of steel with the ductility of a large piece formed from the same material. It vitiated an exact comparison between the ductility of thick plates and thin plates. If they tested a number of plate strips of the same length but of different thicknesses, the thicker plate would contribute more to the percentage during its local elongation, because the local elongation was a function of the diameter and not of the length. It was perfectly easy to separate the local elongation from the general elongation, because the general elongation always ceased as soon as the strength left off increasing and began to diminish. He had therefore, as a little kindred to the subject, taken the opportunity of setting forth that point as worthy of some attention, and as being a point



on the paper ; indeed he had only entered the room when it was half read. He thought it would be desirable to send such papers round to those who were likely to take an interest in them. This was certainly a most valuable paper and one of extreme interest. In the ordinary way of testing for tensile strain, the clamps were attached at such a distance apart as to leave a distance of 8 inches or 10 inches (according to the varying practice of engineers) clear for observation of changes during the test.

He observed that the instrument now under discussion was attached to points close to the clamps. Therefore all the indications would be average indications. Mr. Wicksteed had drawn attention to the deformation that took place after the stop had taken effect. That, no doubt, was very important, and the value of such a diagram would be very considerable ; but it was still only an average of all the changes which took place. It might be assumed that there was no deformation taking place at the points where the clamps were attached. All the deformation took place between the two clamps, and the amount largely depended upon the proportion between the length and the breadth or thickness of the test-bar. The strains that came upon the bar were not all parallel to its axis, which would be so if the bar were a series of fibres unattached laterally. As elongation took place, these lateral attachments caused strains in almost every direction. The consequence was that they had in a test-bar cross strains which came to their maximum at the centre of the bar, and hence it was here that they always found the most marked reduction of area, if the bar was homogeneous.

It was those cross strains that caused this reduction of area, which, when it came to a certain limit, produced rupture. The instrument did not measure those particular changes, and he thought it would be an extremely difficult problem to endeavour to indicate, by means of any instrument, those local changes, unless very short test-bars were used. As a matter of fact, however, they did get a most valuable indication, when they got the average changes that took place.

Some years ago he made some experiments with regard to the perforation of test-bars, and it might surprise some to know that a very considerable increase in the tensile power was obtained





longer support the maximum load, and the beam would rest upon its lower stop until ultimate fracture; but with such an instrument as the one under consideration, the maximum load would be recorded as the load sustained when the test-piece fractured. Engineers and manufacturers recorded the maximum load sustained and the final elongation, these figures forming a convenient basis of comparison for similar metals. So often had these figures been produced side by side that some had regarded these characteristics as associated and observable at the same time in the piece tested. A diagram which could not record the marked decrease in the load sustained when a ductile test-piece began to strangle, not only added nothing to the knowledge of the material, but would appear to give experimental support to a fallacy already widespread.

Upon examining the diagrams produced with the paper, one could only regret the absence of explanatory notes. No. 3, which broke at 20·8 tons per square inch, possibly was a defective sample, as such very mild steel would not usually sustain an increasing load until the instant of fracture, as shown; nor should one expect to find 20·8 tons per square inch associated with only 27·3 per cent. in 8 inches. 24 tons per square inch being commonly found to give 30 to 34 per cent. elongation, and that measured over ten inches, the operator may have failed to balance the straining load, and the test-piece, if measured, might possibly have been found to have stretched more than recorded, such defect being not unknown in existing drum recorders.

Could a portable recorder be devised possessing the power of divination outlined by the author, *i.e.*, indicating at a glance how the material had been treated, judiciously or otherwise, during manufacture, it would be a very useful tool. The author's conception was very comprehensive, his specification very complete, but whether this ideal instrument was materialised in the very ingenious mechanism described was, in his opinion, more than doubtful.

Professor R. H. SMITH agreed with what Mr. Wicksteed had said with regard to the desirability of having autographic diagrams. He thought that Mr. Wicksteed had done them great service when he explained, a few years back, the desirability of



men outside the machine, so that it should be put into the machine and make its record, and then be taken away again and another one come on. He thought that idea would delight Mr. Henning very much. Dr. Elliott had run the instrument down in comparing it with a really autographic recorder. The instrument described in the paper was a mechanical recorder—it was not strictly an autographic one. It did not do its own work independently of the manipulation of the machine. He did not, however, go so far as Dr. Elliott, who had mentioned the rapidity with which changes took place at certain critical points, as doing away with the utility of a mechanical recorder. The benefit of a mechanical recorder was that at the same instant at which the test-piece stretched in an unforeseen way at the yield-point the record was made of the position of the poise: whereas, if they measured with a pair of compasses, with the legs held into the datum points of the specimen, and a yield suddenly took place, the poise was then away. If they called out to the man reading the position of the poise, "Now the piece has yielded," they had lost the record. But the pencil that drew the curve, which was governed by the extension of the specimen, and also the movement of the poise, recorded the two things simultaneously.

There were some complicated tests that they might have to make with riveted joints. Suppose they had eight rivets in a joint with double butt straps in which it happened that there were twenty-four places at which the plates might slip upon the rivets. Each rivet passed through three plates, so that there were twenty-four places where slip might occur. If they wanted to find the best riveted joint, not in regard to ultimate strength, but in regard to the first point at which the plates shifted past each other, which was really the point at which leak or deformation would begin, it would be found easy to do it if they had a mechanical recorder, which would tell where every little slip took place. The first might be so insignificant that it meant nothing but coming home against some slack rivet till all the rivets came to act as pins. Still this little slip showed them where the tightening effect of the rivet heads to bring the faces of the plates together failed to carry more load. It told them all about it; but it was different when trying to do it with one man at the steelyard and another man at the trammel or compasses.













such as clamps, &c., and permit constant ocular inspection of the material under test. The changes occurring at and after stricture commences are purely local, and during this period the other parts of the material remain practically unchanged; hence the latter part of the diagrams after the maximum load-point shows precisely what is transpiring during the period of local contraction just as well as though a short piece had been tested. Mr. H. C. King desires to know where the magnification of the diagram ceased. Diagrams 1 and 2 were made without use of stop, and No. 3 alone shows the point where magnification ceases, and is indicated by the word "stop." I would again emphasise the fact that the instrument requires so little time to be applied to the test-piece, that it is not only a laboratory, but also a practical instrument for routine or commercial testing, wherever the latter is done with any degree of reasonable neatness or accuracy. I must repeat to Mr. King that one of the important objects of a recorder is to serve as a controller of the actions of the person operating the testing machine, and if it shows all the shortcomings of man and machine, one of its most essential missions is fulfilled. I also wish to point out to Mr. King that in a properly made test, the beam must float level up to the very instant of rupture, and never rest against either top or bottom stop; if the latter occurs, the test has been carelessly made. The diagrams show that the instrument records all loads after the maximum carried up to the instant of rupture. Diagram No. 3 is correct, because the test-piece broke suddenly. The elongation of the test-piece by measurement after rupture also agreed with that recorded by the instrument.

The PRESIDENT said he had much pleasure in proposing a hearty vote of thanks to Mr. Henning for his able paper, in which might be included the thanks of the members to Mr. Wicksteed. As their time was drawing to a close, he was afraid that it would be necessary to take the paper on "Spectrographic Analysis of Iron Ores," by Professor Hartley and Mr. Ramage, as read, and also Mr. Louis's paper on "The Iron Industry of Hungary." He would, however, ask the members to pass a hearty vote of thanks to those gentlemen for their contributions.



gauge that work, and therefore could not measure their thanks to Mr. Riches, but their gratitude was certainly very great, and their anticipations for the future were still greater. On behalf of the members, he had very much pleasure in seconding what had fallen in such a modest way from the President. He did not think they had ever had a President more popular than Mr. Martin, and that, he thought, must in some degree be the reason why they were present in such great numbers—500 members, and several hundred ladies in addition. On their behalf, on behalf of the Institute generally, including absentees, he seconded the motion that their grateful thanks be recorded for what had been done, and what was about to be done for their benefit.

The motion was unanimously adopted.

Mr. HEYWOOD, in acknowledging the votes of thanks, said that, in the absence of Sir William Lewis, he had been requested, on behalf of the Reception Committee, to say how much pleasure it gave them to find that their efforts to make the meeting a success had been appreciated. From the first, when it was suggested by the Council to hold this meeting in Cardiff, Sir William Lewis had been most anxious that it should be a record one, and he had certainly worked very hard to make it so. His first suggestion, that Mr. Riches should be the Honorary Secretary, showed how valuable had been his advice throughout. Mr. Whitwell had anticipated what he had intended to say with reference to the labours of Mr. Riches, who, as the Reception Committee well knew, had done all the detailed work, indeed had worked not only throughout the day, but during most of the night. As he might have no other opportunity, he wished, on behalf of the Reception Committee, to thank Mr. Riches for his very valuable services. The measure of their indebtedness to him was the measure of the appreciation of the members of the Institute.

Mr. T. HURRY RICHES said that Mr. Heywood had been very kindly complimentary to him. The best thanks that any Secretary who had his heart in his work could receive was to know or to believe that those whom he had had the pleasure of working



## A SPECTROGRAPHIC ANALYSIS OF IRON ORES AND ASSOCIATED MINERALS.

BY W. N. HARTLEY, F.R.S., AND HUGH RAMAGE, A.R.C.Sc.I., F.I.C., F.C.S.,  
ROYAL COLLEGE OF SCIENCE, DUBLIN.

IN the examination of the spectra of the flame from the converter used in the basic Bessemer process, lines and bands were photographed which were proved to be absent from the flame from the acid process, and yet they could not be attributed to the basic materials of the charge. Some of these lines were characteristic of the rarer metals. They were likewise found in metallic iron from the blast-furnace, in rail-steel, and in aluminium, reduced from alumina obtained from Irish bauxite; in addition, several elements not usually considered as constituents of iron and steel, or of aluminium, were also present, as, for instance, lead, silver, copper, gallium, and chromium.

We were desirous of studying the Bessemer flame in works other than those already visited, but as circumstances have prevented our having the opportunity of carrying on further investigations in this direction, such work for a time has been suspended. Finally, on consideration of the whole subject, it seemed possible to attack the question of the origin of these lines in the spectra from another point of view. Thus, having already proved the volatility of a large number of elements and their compounds in (*a*) the oxyhydrogen flame, and (*b*) the carbonic oxide flame, it seemed a matter of considerable interest to examine a large collection of iron ores for volatile constituents of a metallic nature. By so doing it is easy to ascertain the elements which might be found in the metal smelted therefrom, those to be looked for in the flame from the converter, and those which might be expected to pass into the steel as the final product of such ores.

Having regard to the fact that some of the elements known to present are not volatile at the temperatures employed, such as



difficult to manipulate in an ordinary support of kyanite, the powders were wrapped up in ashless filter-papers, and burnt in the oxyhydrogen flame. Blank experiments were, of course, made with the same paper to ascertain that no impurities were thereby introduced. The spectra were measured, and wave-lengths of the lines determined; when this has once been accomplished, spectra photographed for comparison yield satisfactory results for the purpose of identifying the lines of the elements which are present.

In the paper we have referred to, we sought information concerning the geological distribution of the rarer elements, and of facts helping to elucidate the origin of ore deposits.

The formation of minerals, and of lodes and beds of ore, has been dealt with by Gustave Bischof,\* by Irving and Van Hise, more recently by Professor Franz Posepny† and by S. F. Emmons.‡ In the prosecution of such inquiries we believe that the method pursued by us will prove of considerable value, as it has enabled us to arrive at important generalisations.

*Explanation of the Symbols, Numbers, and Abbreviations used  
in the following Tables.*

In column I. the specimen's number is stated.

Column II. contains the name of the ore or mineral, and its locality. Specimens marked (*a*) are from the Metallurgical Collection of the Royal College of Science; (*b*) from the Science and Art Museum; and (*c*) from the minerals used for analytical practice in the Chemical Laboratory of the Royal College of Science, Dublin; (*d*) minerals purchased recently; (*e*) from Professor J. P. O'Reilly's Collection; (*f*) from the Mineralogical Collection of the Royal College of Science, Dublin.

The symbols following the name of a specimen indicate the elements present in the sample. When plain type is used the lines of the element are very strong in the spectrum of the

\* "Chemical Geology."

† "The Genesis of Ore Deposits," *Transactions of the American Institute of Mining Engineers*, special edition.

‡ "Geological Distribution of the Useful Metals in the United States," *Transactions of the American Institute of Mining Engineers*, vol. xxii. p. 53, 1894. "A Treatise on Ore Deposits," Phillips and Louis, 1896.

specimen. When printed in italics, it indicates that the lines are weak, and traces only of the metal are present.

An index figure after the symbol—thus, Ni 2—indicates the strength of the lines in the spectrum when the element is present in small quantity. When the line or lines are sufficiently distinct to show that the quantity of the element is in excess of mere traces, the figure 1 is used; clear and distinct lines are indicated by 2; stronger lines are represented by numerals up to 9, which figure represents the intensity of the strongest lines seen in the spectrum of that mineral which is at present known to be the richest source of the element in question—thus, Ga 5 and Ga 9. The Bensburg and Piérrefitte blends are richest in gallium, while that of Freiberg is richest in indium. Any ores as rich as these minerals, as determined by comparison with standard photographs, would be represented by Ga 9 or In 9.

The intensity of the lines of silver, copper, and thallium, lead, chromium, nickel, &c., are indicated by a similar scale.



TABLE I.—*The Composition of Iron Ores, chiefly Clay Ironstones, Spatheose Ores, and Black Band.*

I.	II.	Sodium.	Potassium.	Rubidium.	Silver.	Copper.	Calcium.	Gallium.	Nickel.	Manganese.	Chromium.	Lead.
1 {	Calced Cleveland ore, from the North-Eastern	Na	K	?	Ag 1	Cu 2	Ca	Ga 3	..	Mn	Cr 3	Pb 3
2 {	Steel Co.'s Works, Middlesbrough	Na	K	?	Ag 1	Cu 1	Cu	Ga 1	Ni 1	Mn	Cr 1	Pb 2
3 {	Cleveland ironstone, Middlesbrough (a)	Na	K	?	Ag 2	Cu 2	Ca	Ga 2	..	Mn	Cr 3	Pb 2
4 {	Clay ironstone, Yorkshire (a)	Na	K	Rb	Ag 1	Cu 3	Ca	Ga 2	..	Mn	Cr 1	Pb 1
5 {	" Grosmont, Whitby, Yorkshire (a)	Na	K	?	Ag 2	Cu 3	Ca	Ga 1	..	Mn	..	Pb 1
6 {	" Grosmont, Whitby (a)	Na	K	?	Ag 2	Cu 1	Ca	Ga 1	Ni 1	Mn	Cr 1	Pb 1
7 {	" Hedley Collieries, Northumberland	Na	K	?	Ag 2	Cu 1	Ca	Ga 1	..	Mn	..	..
8 {	" Hedley Collieries, calcined (a)	Na	K	?	Ag 1	Cu 1	Ca	Ga 2	..	Mn	..	..
9 {	" Nodules (a)	Na	K	?	Ag 2	Cu 2	Ca	..	..	Mn	..	..
10 {	" Merthyr Tydvil, South Wales (a)	Na	K	?	Ag 2	Cu 3	Ca	Ga 1	..	Mn	..	Pb 3
11 {	" balls, calcined (a)	Na	K	?	Ag 1	Cu 2	Ca	Ga 2	Ni 2	Mn	Cr 1	Pb 1
12 {	" Castlecomer, Co. Kilkenny (a)	Na	K	?	Ag 1	Cu 2	Ca	Ga 1	..	Mn	Cr 2	Pb 3
13 {	" Northamptonshire (a)	Na	K	?	Ag 2	Cu 1	Ca	..	..	Mn	..	..
14 {	Iron spar, Brendon Hill Iron Mines, Somerset-	Na	K	?	Ag 2	Cu 1	Ca	..	..	Mn	..	Pb 2
15 {	shire (a)	Na	K	?	Ag 1	Cu 1	Ca	Ga 1	Ni 1	Mn	Cr 2	Pb 1
16 {	Clay ironstone, Northamptonshire ore, calcined (a)	Na	K	Rb	..	Cu 1	Ca	..	Ni 1	Mn	..	Pb 1
17 {	Calcined ironstone, Normandy Mine, Yorkshire (a)	Na	K	?	Ag 1	Cu 1	Ca	..	Ni 1	Mn	..	..
18 {	Bassy ironstone, Longton, Staffordshire (a)	Na	K	?	Ag 1	Cu 1	Ca	..	..	Mn	..	..
19 {	Bassy ironstone, Longton, calcined (a)	Na	K	?	Ag 1	Cu 1	Ca	..	..	Mn	..	..
20 {	Old Man ironstone, Derbyshire (a)	Na	K	?	Ag 1	Cu 2	Ca	..	..	Mn	..	Pb 3
21 {	Gubbin ironstone (a)	Na	K	Rb	Ag 1	Cu 2	Ca	..	Ni 1	Mn	..	Pb 1
22 {	" " calcined (a)	Na	K	?	Ag 1	Cu 2	Ca	..	..	Mn	..	Pb 1
23 {	Ball ironstone (a)	Na	K	?	Ag 2	Cu 3	Ca	..	..	Mn	..	Pb 1
24 {	" " calcined (a)	Na	K	?	Ag 1	Cu 1	Ca	..	..	Mn	..	Pb 1
25 {	Diamond ironstone, calcined (a)	Na	K	?	Ag 1	Cu 1	Ca	..	..	Mn	..	Pb 3
26 {	White ironstone (a)	Na	K	?	Ag 1	Cu 2	Ca	..	Ni 1	Mn	..	Pb 2
27 {	" " calcined (a)	Na	K	?	Ag 1	Cu 2	Ca	Ga 2	..	Mn	..	Pb 1
28 {	Blue Flats ironstone (a)	Na	K	?	Ag 1	Cu 2	Ca	Ga 1	..	Mn	..	Pb 1

TABLE I.—The Composition of Iron Ores—(Continued)

I.	II.	Sodium	Potassium	Reddish	Silver	Copper	Calcium	Gallium	Indium	Thallium	Iron	Nickel	Manganese	Chromium	Lead
27	Blue Flats ironstone, calcined (a)	Na	K	?	Ag 2	Cu 2	Ca	Ga 1	..	..	Fe	Ni 1	Mn	Cr 1	Pb 1
28	New ironstone, Foley Colliery (a)	Na	K	?	Ag 1	Cu 2	Ca	Ga 1	..	..	Fe	..	Mn	..	Pb 1
29	New Mine ironstone, Foley Colliery (a)	Na	K	?	Ag 1	Cu 1	Ca	..	..	..	Fe	..	Mn	..	Pb 2
30	" " " calcined (a)	Na	K	?	Ag 1	Cu 1	Ca	..	..	..	Fe	..	Mn	..	Pb 3
31	Poor Robin ironstone (a)	Na	K	?	Ag 1	Cu 2	Ca	..	..	..	Fe	..	Mn	..	Pb 1
32	" " " (a)	Na	K	?	Ag 1	Cu 2	Ca	..	..	..	Fe	..	Mn	..	Pb 3
33	Ironstone, Krinsarrei	Na	K	?	Ag 1	Cu 1	Ca	..	..	..	Fe	..	Mn	..	Pb 1
34	" " " (a)	Na	K	?	Ag 1	Cu 1	Ca	..	..	..	Fe	..	Mn	..	Pb 3
35	" " " (a)	Na	K	?	Ag 1	Cu 1	Ca	..	..	..	Fe	..	Mn	..	..
36	" " " (a)	Na	K	?	Ag 2	Cu 2	Ca	Ga 2	..	..	Fe	..	Mn	..	Pb 1
37	" " " (a)	Na	K	?	Ag 2	Cu 2	Ca	Ga 1	..	..	Fe	..	Mn	..	..
38	" " " (a)	Na	K	?	Ag 1	Cu 2	Ca	Ga 2	..	..	Fe	Ni 2	Mn	..	..
39	" " " (a)	Na	K	?	Ag 3	Cu 2	Ca	Ga 1	..	..	Fe	Ni 1	Mn	..	..
40	" " " (a)	Na	K	?	Ag 1	Cu 1	Ca	..	..	..	Fe	..	Mn	..	..
41	" " " (a)	Na	K	?	Ag 1	Cu 1	Ca	..	..	..	Fe	..	Mn	..	..
42	" " " (a)	Na	K	?	Ag 2	Cu 1	Ca	..	..	..	Fe	..	Mn	..	..
43	spars, Calcined	Na	K	?	Ag 1	Cu 2	Ca	..	..	..	Fe	..	Mn	..	Pb 2
44	" " "	Na	K	?	Ag 1	Cu 2	Ca	..	..	..	Fe	..	Mn	..	Pb 3
45	" " "	Na	K	?	Ag 1	Cu 1	Ca	..	..	..	Fe	..	Mn	..	Pb 1
46	Raw	Na	K	?	Ag 1	Cu 2	Ca	..	..	..	Fe	..	Mn	..	..
47	Black ba.	Na	K	?	Ag 1	Cu 1	Ca	Ga 1	..	..	Fe	..	Mn	..	..
48	" " "	Na	K	?	Ag 2	Cu 1	Ca	..	..	..	Fe	..	Mn	..	Pb 1
49	" " "	Na	K	?	Ag 2	Cu 1	Ca	..	..	..	Fe	..	Mn	..	Pb 1
50	" " "	Na	K	?	Ag 2	Cu 1	Ca	..	..	..	Fe	Ni 1	Mn	..	..
51	Mineral	Na	K	?	..	Cu 2	Ca	Ga 2	..	Tl 2	Fe	Ni 2	Mn	Cr 1	Pb 1

TABLE II.—*Brown Hematites.*

I.	II.	Sodium.	Potassium.	Rubidium.	Silver.	Copper.	Calcium.	Gallium.	Indium.	Thallium.	Iron.	Nickel.	Manganese.	Chromium.	Lead.
52	Pistolitic hæmatite, Louveigneur (a)	Na	K	Rb	Ag 2	Cu 2	Ca	Ga 2	..	..	Fe	Ni 1	Mn	Cr 2	Pb 1
53	Brown hæmatite, Aryleur, near Liège (a)	Na	K	?	Ag 1	Cu 3	Ca	..	..	..	Fe	..	Mn	..	Pb 2
54	" " St. Maur, Meuse (a)	Na	K	?	Ag 2	Cu 3	Ca	Ga 1	..	Tl 1	Fe	Ni 3	Mn	Cr 1	Pb 1
55	" " Graux, S. W. of Namur (a)	Na	K	?	Ag 1	Cu 2	Ca	..	..	Tl 3	Fe	Ni 3	Mn	Cr 1	Pb 9
56	" " Werbomont (a)	Na	K	?	...	Cu 2	Ca	..	..	..	Fe	Ni 1	Mn	..	...
57	" " Cornwall (a)	Na	K	?	Ag 1	Cu 1	Ca	..	In 1	..	Fe	Ni 1	Mn	..	Pb 1

TABLE III.—*Limonites.*

58	Limonite, locality unknown (a)	Na	K	?	Ag 1	Cu 4	Ca	..	..	Tl 1	Fe	Ni 4	Mn	Cr 2	Pb 1
59	" Langenstrieigés, Saxony (d)	Na	K	?	Ag 3	Cu 4	Ca	..	..	..	Fe	Ni 2	Mn	..	Pb 4
60	" Lercoul, Arriege, France (d)	Na	K 1	?	Ag 1	...	Ca	..	..	..	Fe	..	Mn	..	...
61	" Fleetwood, Pennsylvania, U.S.A. (d)	Na	K	?	Ag 1	...	Ca	Ga 1	..	..	Fe	...	Mn	..	Pb 1
62	Bog iron ore, Ippendorf, Rhine (d)	Na	K	?	Ag 1	Cu 1	..	..	..	..	Fe	Ni 1	Mn	..	Pb 1

TABLE IV.—*Real Hematites.*

I.	II.	Sodium.	Potassium.	Rubidium.	Silver.	Copper.	Calcium.	Gallium.	Indium.	Thallium.	Iron.	Nickel.	Manganese.	Chromium.	Lead.
63	Hæmatite, Osnaburg, Germany (b)	Na	K	...	Ag 1	Cu 2	Ca	...	In 1	...	Fe	Ni 1	Mn	Cr 2	Pb 4
64	" Haycock Mine, Ontario, Canada (b)	Na	K	...	...	Cu 1	Ca	...	...	...	Fe	...	Mn	...	Pb 1
65	" Esvenstock, Saxony (b)	Na	K	...	Ag 1	Cu 1	...	...	...	...	Fe	...	Mn	...	Pb 1
66	" Altenburg, Saxony (b)	Na	K	...	Ag 1	...	Ca	...	In 1	...	Fe	...	Mn	...	Pb 3
67 {	" Schwarzenberg (b)	Na	K	Rb 2	Ag 1	Cu 5	Cu	Ga 1	In 2	Tl 3	Fe	...	Mn	...	Pb 4
68	" Erzgebirge (b)	Na	K	...	Ag 1	Cu 1	Ca	Ga 1	...	...	Fe	Ni 1	Mn	...	Pb 2
69	" Schneeberg, Saxony (b)	Na	K	...	...	Cu 1	...	...	...	...	Fe	...	Mn	...	Pb 1
70	" Elba (b)	Na	K	...	...	Cu 1	Ca	...	...	...	Fe	...	Mn	...	...
71	" Cleator Moor, Cumberland (d)	Na	K	...	Ag 1	Cu 1	...	...	...	...	Fe	...	...	...	...
72	" Antwerp, New York (d)	Na	K	...	Ag 1	Cu 1	...	...	...	...	Fe	...	...	...	...
73	" Iron Glance, Elba (d)	Na	K	...	Ag 3	Cu 1	...	...	...	...	Fe	...	...	...	...
74	" " Canada (d)	Na	K	...	Ag 2	Cu 1	...	...	...	...	Fe	...	...	...	...
75	" " Norberg, Sweden (d)	Na	K	...	Ag 2	Cu 1	Ca	...	...	...	Fe	...	Mn	...	Pb 1
76	" Iron ore, Styria (b)	Na	K	...	Ag 1	Cu 2	Ca	...	...	...	Fe	...	Mn	...	Pb 1
77	" Hæmatite, Llantrissant, Wales (a)	Na	K	?	Ag 1	Cu 1	Ca	...	...	...	Fe	...	Mn	...	Pb 2
78	" Specular iron ore (a)	Na	K	...	...	Cu 1	Ca	Ga 1	...	...	Fe	...	Mn	...	Pb 1
79	" " Darlkarlsberg, Sweden (a)	Na	K	?	Ag	Cu 1	Ca	...	...	...	Fe	...	Mn	...	Pb 1
	" " Mossaberg, Sweden (a)	Na	K	...	...	Cu 1	Ca	...	...	...	Fe	...	Mn	...	Pb 1

TABLE V.—*Magnetites.*

		Sodium.	Potassium.	Rubidium.	Silver.	Copper.	Calcium.	Gallium.	Indium.	Thallium.	Iron.	Nickel.	Manganese.	Chromium.	Lead.
80	Magnetite, Moria Mine, Essex Co., New York (d)	Na	K	?	Ag 1	Cu 1	Ca	Ga 1	...	...	Fe	...	Mn	...	...
81	" " Ozarka Mountains, Arkansas (d)	Na	K	...	Ag 1	Cu 1	Ca	Ga 2	...	...	Fe	...	Mn	...	Pb
82	" Opdal Skage, Namsa, Norway (d)	Na	K	...	Ag 1	Cu 2	Ca	Ga 1	...	...	Fe	...	Mn	...	Pb
83	Magnetic iron ore, Darlkarlsberg, Sweden (a)	Na	K	?	Ag 2	Cu 1	Ca	Ga 2	...	...	Fe	...	Mn	...	Pb
84	" " Bispberg, Sweden (a)	Na	K	?	Ag 1	Cu 1	Ca	Ga 2	...	...	Fe	...	Mn	...	Pb
85	" " Dannemora, Sweden (a)	Na	K	?	Ag 1	Cu 1	Ca	Ga 1	In 2	...	Fe	...	Mn	...	Pb
86 {	Magnetic iron sand, washed from sand in Bray Strand, Co. Dublin	Na	K	...	Ag 1	Cu 1	Ca	Ga 1	...	...	Fe	...	Mn	...	Pb



TABLE VIII.—Various Manganese Ores and Minerals.

I.	II.	Sodium	Potassium	Rubidium	Barium	Copper	Calcium	Gallium	Indium	Thallium	Iron	Nickel	Manganese	Chromium	Lead
109	Spanish ore, 15% Mn., used at Middlesbrough	Na	K	..	Ag 2	Cu 1	Ca	..	In 1	..	Fe	Ni 3	Mn	..	Pb 8
110	Pyrolusite, Geissen, Saxony (d)	Na	K	Rb 1	Ag 1	Cu 3	Ca	..	..	Tl 3	Fe	Ni 3	Mn	..	..
111	" Ilmenau, Thuringia (d)	Na	K	Rb 2	Ag 1	Cu 3	Ca	..	..	..	Fe	Ni 1	Mn	..	..
112	Psilomelane, near Dolgelly, N. Wales (d)	Na	K	..	Ag 1	Cu 1	Ca	Ga 1	..	..	Fe	Ni 1	Mn	..	..
113	" Llorca, Spain (d)	Na	K	Rb 3	Ag 1	Cu 4	Ca	Ga 3	..	..	Fe	Ni 4	Mn	..	..
114	" Siegen, Westphalia (d)	Na	K	Rb 2	Ag 1	Cu 2	Ca	..	..	..	Fe	Ni 1	Mn	..	..
115	Rhodonite, near Dolgelly, N. Wales (d)	Na	K	..	Ag 1	Cu 1	Ca	..	..	..	Fe	Ni 1	Mn	..	Pb 5
116	" Paisberg, Sweden (d)	Na	K	..	Ag 1	Cu 1	Cu	..	..	..	Fe	..	Mn	..	Pb 2
117	Pyrolusite, locality unknown (c)	Na	K	Rb 2	Ag 1	Cu 6	Ca	Ga 1	..	Tl 2	Fe	..	Mn	..	Pb 4
118	Manganite, locality unknown (c)	Na	K	..	Ag 1	Cu 4	Ca	..	..	Tl 3	Fe	..	Mn	..	Pb
119	The same, 25 grams used	Na	K	..	Ag	Cu	Ca	Ga	..	Tl	Fe	Ni	Mn	..	..
120	Franklinite, locality unknown (d)	Na	K	..	..	Cu 1	Ca	..	..	..	Fe	..	Mn	..	..

TABLE IX.—Pyrites.

157	Iron pyrites, Wheal Lane, Cornwall (d)	Na	K	..	Ag 3	Cu 4	Ca	..	..	..	Fe	Ni 3	Mn	..	Pb 3
158	Marcauite, radiated, Dover (d)	Na	K	..	Ag 1	Cu 1	Ca	..	..	..	Fe	..	Mn	..	Pb 1
159	Iron pyrites, Esna, Norway (d)	Na	K	..	Ag 1	Cu 8	Ca	Ga 1	..	..	Fe	Ni 9	Mn	..	..
160	Pyrrhotite, Rom, Smallemul, Norway (d)	Na	K	..	Ag 2	Cu 7	Ca	..	..	..	Fe	Ni 3	Mn	..	Pb 1
161	" Anden, Bamle, Norway (d)	Na	K	..	Ag 2	Cu 9	Ca	..	..	..	Fe	Ni 1	Mn	..	Pb 6
162	Pyrites, Staffordshire (b)	Na	K	..	Ag 1	Cu 1	Ca	..	..	..	Fe	..	Mn	..	Pb 3
163	" Roschau (b)	Na	K	..	Ag 1	Cu 1	Ca	..	..	..	Fe	..	Mn	..	Pb 3
164	" Freiberg, Saxony (b)	Na	K	..	Ag 1	Cu 1	Ca	..	..	..	Fe	..	Mn	..	Pb 2
165	" Schemnitz, Hungary (b)	Na	K	..	Ag 5	Cu 1	Ca	..	..	..	Fe	..	Mn	..	Pb 5
166	" Isle of Elba (b)	Na	K	..	Ag 1	Cu 5	Ca	..	..	..	Fe	..	Mn	..	Pb 1
167	" Goslar, Harz (b)	Na	K	..	Ag 1	Cu 1	Ca	..	..	..	Fe	..	Mn	..	Pb 1
168	" Joachimsthal, Bohemia (b)	Na	K	..	Ag 1	Cu 1	Ca	..	..	..	Fe	..	Mn	..	Pb 1
169	Chalcopyrite, locality unknown (c)	Na	K	..	Ag 2	Cu	Ca	..	..	..	Fe	Ni 2	..	..	Pb 1

We have found lithium almost invariably in iron ores, and it occurs in Bessemer flame spectra; but, as a rule, it is not photographed, and our knowledge of its presence depends upon eye-observations of the red line. On this account it is not included in the tables. The presence of rubidium is very frequent, but where a note of interrogation (?) appears under this head, it implies that the lines in the spectrum were overpowered by closely-adjacent lines of iron.

It is a marked characteristic of siderites that they contain indium, and of magnetites that they contain gallium. Ores derived from the older rocks, such as bauxites from basalts, contain chromium, nickel, and gallium.

In clay-ironstones, gallium has been found in twenty-one out of fifty-one specimens; chromium frequently occurs along with it; and in the same ores both metals are occasionally associated with nickel.

Thallium is of rare occurrence in oxide ores of whatever variety, but it is frequent in pyrites. Indium, too, occurs in many specimens of pyrites, but gallium comparatively rarely.

Red hæmatites are ores of great purity.

It follows from this investigation that the ores used, when submitted to the same method of examination, afford us very decided indications of the lines to be looked for in the flame-spectra of the Bessemer blow.





which was used for rails, tires, axles, plates, and merchant steel, the latter consuming 145 tons. At Diósgyőr a Bessemer plant had been completed, and was shortly to be started; the annual production of finished iron and steel in Hungary being then 112,272 tons. The iron ore districts were situated then, as now, in the following counties:—Gömör, Zips, Abauj-Torna, Sohl, Borsod, Marmaros, Hunyad and Krassó-Szörény. The deposits extend in a sort of semicircular belt from the west by north-west, north, and east to the south, uniting to form a characteristic group in the north-west. The ores are mostly carbonates in the upper beds, outcrops, and contacts merging into brown iron ore in depth, which varies with different localities. Other ores are frequently associated with the iron ore, but do not prevail in depth, and anyway present no great difficulties in separation. In the past, copper, lead, and silver mines and works existed where iron mines and works are now found, and the waste heaps of the earlier times provide material for the blast-furnaces of to-day. The annual production of iron ore of recent years has been as follows:—

1881 to 1885 . . . .	582,435 tons of a value of about £140,952
1886 to 1890 . . . .	658,768 „ „ „ £139,204
More recently . . . .	973,431 „ „ „ £196,273

And the output of iron and steel in Hungary is approximately as follows:—Pig iron, 350,000 tons; castings, 36,000 tons; Bessemer, basic, and open-hearth steel, 250,000 tons; finished wrought iron and steel, 260,000 tons; these having a value of about £2,625,000. The development of the iron industry in Hungary has, therefore, kept pace with the general industrial progress; and whereas the consumption per head of the population in Hungary was 35 lbs. in 1882, it is now about 53 lbs., in spite of the increase in the number of inhabitants. There is, however, still the lack of fuel to face in the production of pig that will keep that department comparatively backward. The other departments of the iron industry are more favourably situated in this respect, inasmuch as gaseous fuel is applied for heating, and this factor has, too, been brought to a fair state of efficiency, which, coupled with the good quality of the charcoal iron, has contributed in a great measure to the considerable development in the production of wrought iron and steel indicated, and to the



The county of Sohl is situated at the north-west portion of the semicircular iron-bearing belt. It is regarded as the nursery of the iron industry in Hungary, but now only boasts of one blast-furnace at Libet, of the dimensions indicated in Table I. The ore smelted is a silicate containing 30–32 per cent. of iron. It is obtained from a contact vein, situated between Lower Permian dolomite and trachytic tuff, being some 26 feet thick, enlarging at places to a stockwork 400 feet thick. It is wrought by main roads, with cross levels at right angles. The annual output is 4000 tons; the ore being conveyed from the mine at Libet by an inclined road to the furnace, about seven miles distant. There the equipment includes a blowing-engine, consisting of two horizontal cylinders, driven, when there is water, by an overshot wheel, otherwise by a 30 horse-power engine; a calcining kiln and a cupola furnace. The blast is heated by the waste gases from the blast-furnace. The output is some 1100 tons of pig, and from 400 to 500 tons of castings. The pig is of excellent quality, as testified by exhibits, and is utilised in the neighbouring towns and at the State refinery at Brezo in Sohl. The State owns about  $73\frac{1}{8}$  per cent. of the whole concern, which is kept going even at a sacrifice on account of the poverty of the neighbourhood.

Gömör county is the leading producer of pig iron in Hungary; it has the richest ore, the largest deposits, most furnaces and greatest output. Of the deposits, one rests on chloritic schist, has a roof of clay and siliceous slate, and is divided into three ore bands by intermediate layers of clay, slate, and grauwacke. The ore bands vary in thickness from 3 to 100 feet; this deposit is proved from 2 to  $2\frac{1}{2}$  miles in the direction of the strike, which is east and west, and from about 300 to 330 yards on the dip, which is to the south. The ore is brown hæmatite, with pockets of clay iron ore and ochre, with carbonates at places. Another deposit between grauwacke and slates is divided into two by an intermediate layer of slate. The chief ore band is 32 to 150 feet thick; it has been traced for more than 760 yards along the strike, and about 220 yards in the direction of the dip. The ore is brown ironstone. There are other deposits of mangiferous and carbonate iron ores in this, the western part of the county, the Vashegy district. Here there are four great owners—the



with eleven boilers. The engines are compound, with high-pressure cylinder 43·31 inches diameter, and low-pressure 64·96 inches; the air-cylinders being 88·58 inches; the stroke 66·93 inches, and 25 per minute. The boilers are gas-heated water-tube, each with a heating surface of 2415 square feet. Pumps supplying 60 cubic feet of water a minute are worked by a 60 horse-power Girard turbine in the river Rima, which also furnishes power to the workshops; there is a steam-pump, however, in reserve.

The ropeway, of 8½ miles extent, is driven by a 100 horse-power steam-engine, is provided with 640 buckets, each of a capacity of 6½ cwts., and carries 250 to 300 tons a day. There are employed 450 men, foremen, &c., at the furnaces, and 80 at the ropeway.

The chemical character of the iron produced is here set forth :—

	Si.	Mn.	Total C.	Graphite.	Cu.	P.	S.	Fe.
White . . .	0·30	2·40	2·60	0·28	0·007	0·56	0·037	94·096
Mottled . . .	0·96	3·06	3·73	3·01	0·006	0·59	0·054	91·55
Grey . . .	3·15	1·86	3·96	3·22	0·004	0·62	0·048	90·36

At Nyustya, less than two miles from Liker, the same company have a blast-furnace and foundry for the production of castings from the Vashegy and Rakos ores, which are brought by means of a ropeway. The blast-furnace is about 33 feet high, 9 feet 4 inches diameter at the bosh, 4 feet 4 inches at the throat, 4 feet 6 inches in the crucible. It is worked with charcoal obtained from the company's forests, and furnished with blast by a three-cylinder vertical blowing-machine worked by a 30 horse-power water-wheel, the blast being heated by two Gjers' stoves, having together 3655 square feet heating surface. The yield is about 55 to 60 tons of grey pig iron weekly, most of which is used up in direct castings, but a cupola is also used for casting work; the yearly output is about 2000 tons of pig iron and 3000 tons of castings; 110 workers are employed at this place.

The character of the iron and slag is shown below :—

	Si.	Mn.	C.	Cu.	P.	S.	Fe.
Grey pig iron . .	1·5	1·8	3·69	0·009	0·65	0·906	92·376

	SiO <sub>2</sub>	Al <sub>2</sub> O <sub>3</sub>	MnO.	FeO.	CuO.	MgO.	Alkalies	P <sub>2</sub> O <sub>5</sub>
Slag . .	52·10	6·05	4·45	1·71	30·28	3·69	0·043	0·60

The exhibit of this company will be referred to later on.



The deposits are from 20 to 80 feet thick, and rest on diorite. They are rather inaccessible, and as the ore is only 28 to 35 per cent. stuff, the exploitation is not commensurate with the development or magnitude of the deposits. The deposits at the headwaters of the river Sajo are more favourably situated, and again is found the association of quartz and fahlore, and also calcspar and ankerite. The great owners are the Duke Philip of Saxe-Coburg-Gotha, who quarries about 10,000 tons of ore, and the township of Dobsina, which puts out 12,000 tons of ore to supply two charcoal blast-furnaces 40 feet high, producing about 6500 tons of pig for the finery. The Government is the next owner, but does not work these mines, and Count Géza Andrassy, who has a vast acreage, produces annually 75,000 tons of ore, containing about 38 per cent. of iron, 2 per cent. of manganese, 0·02 per cent. of phosphorus, and 0·15 per cent. of sulphur. A tramway with inclines is used for transport of the ore to the blast-furnaces, which are eight in number, from 40 to 60 feet high, with an annual production of from 4000 to 6000 tons each; blowing-engines worked by water-power are used. Four of the furnaces provide Bessemer pig, three for the finery, and one for the foundry. The annual consumption of charcoal is 30,000 tons. Count Dionys Andrassy produces 15,700 tons of ore, which is smelted in a 42-foot furnace, producing 4000 tons of castings, most being direct from the blast-furnace. Another firm extracts and uses 18,000 tons of the ore of this neighbourhood.

Milos Milosevich has made a special communication concerning the development of the pig iron industry in Gömör county. He shows how the local circumstances have favoured it, strong deposits of ore and dense forests, so that the industry has flourished there since the Middle Ages, and the methods and practices have been handed down from father to son, so that the ironworkers have characteristics that distinguish them from the other local inhabitants. As regards recent progress, it is pointed out that in 1867 the ore output of the county was 111,228 tons, employing 1639 people. In 1894 the ore output was 320,617 tons, with 2145 workers; or, while the output had increased nearly threefold, the number of workers employed had only increased by about one-third, this being due to the improved









kilns; they are heated by gas admitted below the upper chamber, are circular, and have the form shown in Plate IX., being constructed from the plans of the director, M. E. Holz, and serve for the coarse ore, yielding from 65 to 80 tons of calcined ore per twenty-four hours; there are four of these furnaces. The fine ore is calcined in a Möser reverberatory with a long inclined bottom, exposing a heating surface of 344 square feet, and capable of firing 40 to 50 tons of calcined ore per twenty-four hours, with a consumption of 18 to 20 lbs. of brown coal per ton; the loss in calcining being 20 per cent. There are other deposits of iron ore in Borsod County, but they are unimportant, and the same may be said of the north and north-east of Hungary generally—the whole production from the four blast-furnaces in that region being 4500 tons of pig iron and castings combined.

Turning now to the south-east, Hunyad county is the first encountered, and in it are the strongest brown iron ore deposits of Hungary. They played an important part in the production of iron in very remote times; in fact, there was exhibited in the Exhibition a portion of a furnace found near Gyalar. It had been cut out of the rock, and is supposed to date a thousand years back. It is semicircular in girth, is 2 feet in diameter at the chimney, and 1 foot outside at the bottom of the hearth; its total depth being  $5\frac{1}{2}$  feet, being about 4 feet below the chimney. It is lined with refractory material (see Fig. 1). A block of iron was found in it. The working pit is about 3 feet from the centre of the furnace, being roughly rectangular, and about 2 feet square and 1 foot deep. The chimney is 5 inches in diameter, and it will be observed that a charging platform was erected, and that the furnace was furnished with a cover. The rocks of the district are highly metamorphic, being principally undulatory beds of clay, slates, and then micaceous schists, containing in some places much felspar, and even giving place to gneiss at times; in addition, crystalline limestones and many other sedimentary rocks are well represented, whilst amongst eruptive rocks trachyte and basalt figure. The lateral extension of the deposits is very variable; in fact, they appear to consist of a broken series of irregular masses. The particular mass owned by the State at Gyalar is over 500 feet thick, and consists almost exclusively of limonite embedded in micaceous schists and



5½ feet between the tuyeres, 8½ feet at the boshes, 5 feet 7 inches at the throat, and of a capacity of 1589½ cubic feet; the fuel is exclusively beech charcoal. The blast is obtained from a two-cylinder vertical blower, worked by an overshot water-wheel of 30 horse-power. The product is grey, white, and mottled pig iron, and a small quantity of direct castings. Heavier castings are run from a cupola. Its annual output is 8124 tons of pig, and 141 tons of castings. This furnace was not sufficient to keep pace with the development of the mines at Gyalar, so the foundry at Vajda-Hunyad was started with two charcoal furnaces. The one was blown in in 1885, and has worked up to the present without interruption; the other was blown in a year before, whilst a third was erected in 1890, and blown in in 1891, and is shown in Plate X. Two other blast-furnaces differ somewhat from these in dimensions.

The furnaces, supported on cast-iron pillars, are closed both throat and mouth, with central take-off. They have four tuyere holes, each 4 to 5 inches. The blast pressure is 2·36 to 3·14 inches of mercury; it is furnished by six vertical cylinders worked by a turbine and two steam-engines of 100, 50, and 150 horse-power respectively. The blast is heated by three Whitwell stoves 39½ feet high and 16½ feet in diameter, and three iron pipe apparatus of considerable heating surface. The three charcoal blast-furnaces produce about 49,396 tons of pig, and 1300 tons of castings, destined for consumption in the State works. The output of Govasdia and Vajda-Hunyad combined being insufficient to supply the State fineries and steelworks at Diósgyör, a coke furnace of 40,000 tons capacity was projected in 1894, and blown in in 1895. Its total height is 65½ feet, its working height 59 feet, with a capacity of 10,170 cubic feet; the diameter being 7½ feet in the crucible, 18½ feet at the boshes, and 15 feet 1 inch at the mouth. It is furnished with six tuyeres. The output is 100 tons Bessemer pig iron daily.

The blast is furnished by a quick-running, 50 to 60 strokes of 53·15 inches, compound blower, with high-pressure cylinder 28·44 inches in diameter, low-pressure cylinder 45·28 inches in diameter, and air-cylinder 81½ inches in diameter; each cover is fitted with thirty suction and fifteen pressure valves, very light and frictionless, so together 180 valves, any of which can



thickness of 650 feet and more. In the northern part of the deposit at Vaskö, iron ores prevail, mainly magnetic oxide; in the southern portion, at Dognacska, lead and copper ores prevail, and brown and red hæmatite, as well as magnetic oxide are found. The deposits are worked open-cast or underground according to circumstances. In the extreme north of the district blocks of excellent red hæmatite and magnetic oxide, 100 cubic feet or more in bulk, are found in fault fissures, along with varying sized lumps of all kinds of rocks of the neighbourhood, which are separated from the ironstone by a system of washing, which furnishes 3000 to 4000 tons of iron ore. The ore is conveyed to the railway by an inclined tramway, and by rail to Bogsan or Resicza, some being transhipped at Bogsan for Anina. The output of ore at Vaskö is 101,266, at Dognacska 29,203 tons. The washed ore contains 45·29 per cent. iron and 18 per cent. silica: the other ores average—

	Fe.	Mn.	SiO <sub>2</sub> .	Al <sub>2</sub> O <sub>3</sub> .	CaO.	MgO.	P <sub>2</sub> O <sub>5</sub> .	S.	Cu.
Vaskö . . .	41·5	1·4	20·4	4·0	9·0	2·0	0·2	0·09	0·02
Dognacska .	34·0	0·3	18·3	3·0	7·0	0·4	01·4	0·15	0·16

At Resicza there are two charcoal blast-furnaces 55½ feet high, and 4520 cubic feet capacity, of modern construction, and one coke blast-furnace 65½ feet in height and 9781 cubic feet capacity. The blast is furnished by three engines, but a new compound horizontal engine of 800 horse-power is being constructed to do this work. It is heated by eight Whitwell stoves, six of which are 52½ feet high, with 3281 square feet heating surface, and two are 64½ feet high, and over 6000 square feet heating surface. The greater part of the iron ore is calcined in furnaces 20 feet high with a maximum diameter of 14½ feet, of which there are six, each of a capacity of 6½ tons a day, fed with small coal. The charcoal furnaces produce together per annum 23,000 tons of Bessemer pig, and the coke furnace as much as 22,000 tons. There is a large foundry attached to the works, with six reverberatories and two cupolas, which produce 3800 tons of castings, principally parts of machinery, grooved and hardened rollers, pipes, and merchant castings.

The blast-furnace at Bogsan is 44 feet high, 4½ feet in the





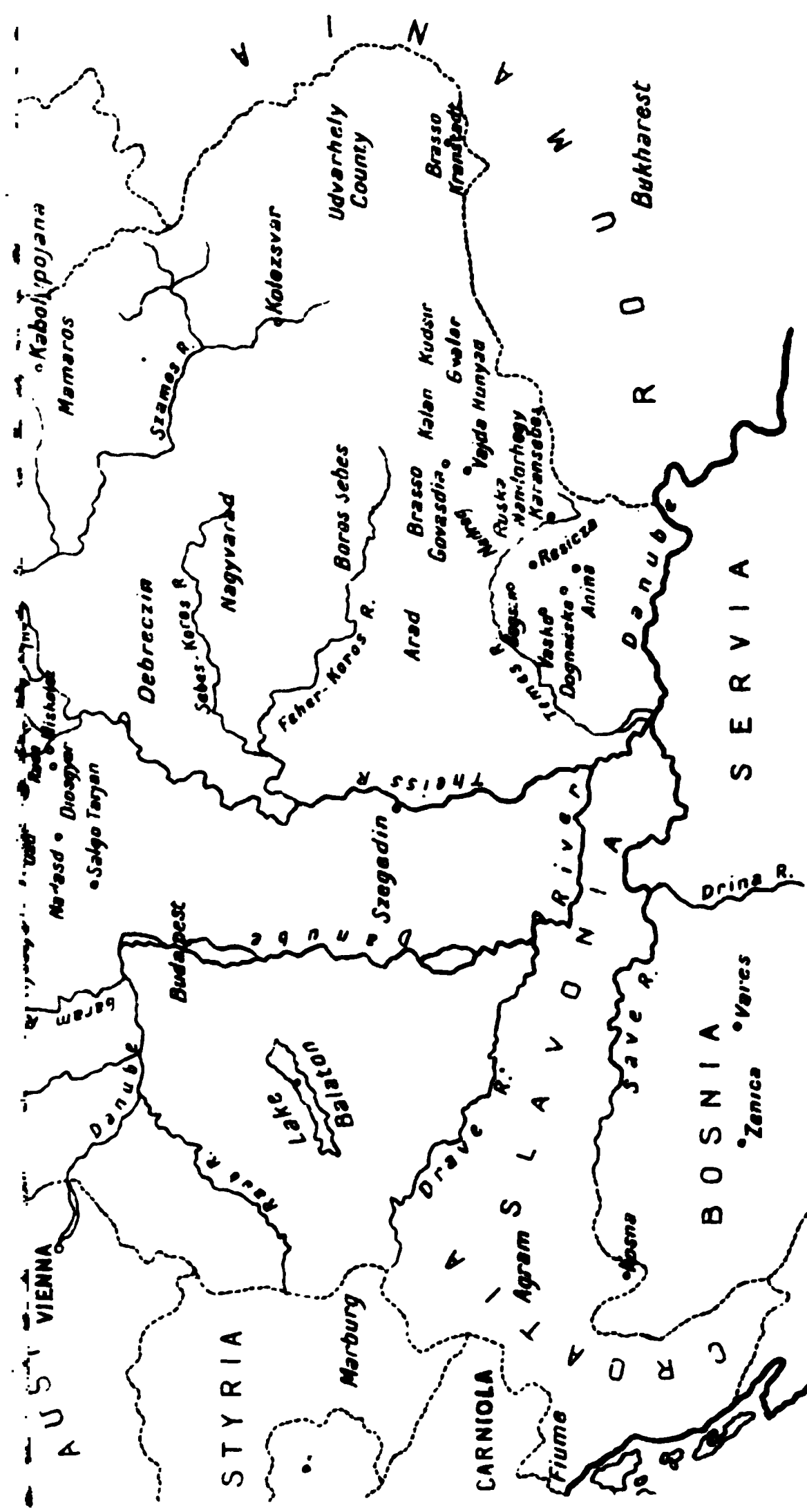


















Zolyom-Brezo (Brezo in Sohl) all being represented. They give employment to 5570 hands, and work iron and steel of an annual value amounting to about £660,000. The exhibits comprised specimens of ores, fluxes, fuels and produce, to which were appended labels with the numbers from the analyses; plans, reproductions, models, and reliefs of the mines and examples of the appliances and of the methods of working; plans and drawings of the various works, and pictorial representations and models of blast-furnaces; also particulars of dwellings, hospitals, laboratories, &c., making an interesting and complete display. It should here be added that the Rimamurany Co. and the Privileged State Railway Co. made equally comprehensive and complete displays in their own pavilions, and other firms were well represented, if not to quite such an elaborate extent; and, without particularising, it may be said that in general the character of the iron and steel, pig or ingot or manufactured, as demonstrated by fractures and tests, was very good. Here are a few examples of tests:—

	Tensile Strength, Lbs. per Sq. In.	Contraction per Cent.	Elongation per Cent.
State puddled iron plate . .	46,500	31·1	16·5
„ „ „ „ „ . .	48,900	30·5	14·0
„ Open-hearth steel angle . .	60,880	54·5	24·0
„ „ „ „ „ . .	64,570	53·7	24·5
„ „ „ channel . .	55,750	59·9	26·5
„ „ „ „ „ . .	60,880	54·5	24·0
Rimamurany basic rails . .	83,060	30·1	20·0
„ „ „ „ „ . .	82,960	56·2	22·5
„ „ „ plate . .	64,570	64·6	31·0
„ „ „ „ „ . .	54,620	69·4	28·0
„ „ „ girders . .	60,170	66·4	29·4
„ „ „ „ „ . .	52,970	58·5	32·7

The spirit with which the private firms entered into the national display that was made at the Exhibition may be gathered from the following data relating to the area covered by their special buildings and the money expended on them. The Rimamurany Salgo-Tarjan Ironworks Company's building covered an area of 960 square yards and cost £2333; the Privileged Austria-Hungarian State Railway Company's pavilion, 576 square yards and £4167; the "Union" Company, 120 square yards and £417;



Vashegy mine produces about 96,300 tons of ore annually, and employs 420 workpeople; the ore being of mixed character—spathic ore, with an average of 38 per cent. of iron, 8 of manganese, and 10 insoluble in acids; black ore, with 46 of iron and 10 of manganese; all varieties of brown ore (limonite), with 46 of iron and 4 of manganese; also hæmatite.

Rakos mine, a mile and three furlongs away, has recently been equipped with a compound winding-engine and two Worthington pumps with a capacity of 264 gallons a minute, with two boilers having 1632 square feet of heating surface, the shaft having been sunk to a depth of 160 fathoms. The ore is a 38 per cent. ore, siliceous limonite above, siderite below; the output is some 50,000 tons a year, which is conveyed  $2\frac{1}{2}$  miles by a  $20\frac{1}{2}$ -inch gauge railway; 185 people are employed. At Jaszo a spathic ore, 39 per cent. iron, 2·5 manganese, mixed with quartz and copper and iron pyrites, is produced, the output being 29,400 tons a year; the ore is roasted on the spot, and conveyed by the State Railway to Liker. Here electrical drills are employed and 250 workpeople.

The Rako mine is a 30 to 34 per cent. brown ironstone in a limestone county, but on account of the low grade and distance from a railway is not worked. The Schmölnitz property has an area of  $117\frac{1}{2}$  acres, and has a deposit of spathic ore in crystalline schist; it is 3 to 13 feet thick, and has been proved for a mile and seven furlongs on the strike and for about 260 feet on the dip, which is  $40^{\circ}$  to  $60^{\circ}$  to the south. The ore is dense, solid, coarsely crystalline, and of exceptional purity; it contains 39 per cent. of iron and 2 per cent of manganese. For want of proper rail communication it is not worked, but is held in reserve. The Slovinka property has hitherto been worked by others for silver and copper, and as an iron mine is not yet productive, but will be in the future. The company also own a quarry of very good limestone, only  $1\frac{1}{2}$  per cent. insoluble in acid, which, with the aid of 80 workers, produces about 69,500 tons of limestone and 9900 tons of lime, to supply the company's blast-furnaces and steelworks. The property abuts on the Tiszolcz station of the State Railway, and the produce is loaded into the waggons for despatch to the various destinations.

The blast-furnace installations of this company at Nyustya







bridge-bars and large spaces below for dealing with the large quantity of ashes. Of course, there are producers in all the other works to which I have referred. In the basic lining shop there is a shaft kiln for calcining the dolomite, a drying kiln, a mixing mill, and a mortar mill for grinding the dolomite. There are three 8-ton converters alternately put in blast, two coke-fired cupolas for melting the pig, one hydraulic platform and two hydraulic ingot cranes; there are underground conveyors for taking the ingots to the soaking pits, which are heated by gas. The blowing-engine is a 780 horse-power twin engine, with steam-cylinder 31 inches, air cylinder  $47\frac{1}{2}$  inches, stroke 49 inches, revolutions 35 to 40, and gives 7063 cubic feet of air at 30 lbs. pressure per minute. This basic Bessemer installation has a capacity of 70,000 tons a year.

The mill has five trains of rolls, two soaking pits and five welding furnaces, and all the necessary shears, saws pendant and otherwise, cranes, live rollers, &c. The heavy work mill consists of four sets of reversing rolls, worked by a 2000 horse-power twin engine, which also serves for the plate-mills, consisting of a set of  $31\frac{1}{2}$ -inch rolls, 10 feet long, as exhibited in the Budapest Exhibition. The section mill has three sets of  $23\frac{3}{4}$ -inch rolls driven by a 700 horse-power engine. The wire-bar mill, two sets of 14-inch roughing rolls, and seven sets of 10-inch finishing rolls, driven by a 750 horse-power Collmann twin engine, which also drives the light bar mill of one three-high roughing set and six finishing sets. A foundry is attached to the steelworks to supply rolls and wheels. Sixteen boilers with double steam chambers, each with 5650 square feet heating surface, furnish all the steam, which is economised by a central condenser installation connected with some of the engines; there is also a water-purifying installation. Coal is brought from the company's mines  $4\frac{3}{8}$  miles away by an adhesion and rack railway; the pig comes from the Liker blast-furnaces, the works being connected by a branch to the State railway at Salgo-Tarjan station. The Salgo-Tarjan works give employment to 1500 hands.

This company produces annually, from all sources, 129,299 tons of ironstone, worth £32,325; 75,547 tons of pig, worth £58,444; 4030 tons of castings and 100,000 tons of finished goods, besides





open-hearth plant consisted of four 8-ton and two 15-ton open-hearth furnaces, with all necessary hydraulic cranes and other accessories. The output is here 30,000 tons of ingots. This is all being reorganised, and converters and larger hearth-

	AT VASKO AND DOGNACSHA.....	
	AT VASKO	=====
THOUSANDS	AT DOGNACSHA	-----

DIAGRAM 1.—Total Production of Iron Ore, 1882-1896.

furnaces are being accommodated in one building, with a long general casting pit. The output of open-hearth steel will be increased to 45,000 or 50,000 tons a year, but the Bessemer output will remain unaltered. For tool, &c., steel there is crucible steelworks giving an output of 1000 tons a year. The crucibles



There is a puddling forge, 312 feet long and 135 feet wide, with two Pietzka revolving furnaces, two ordinary puddling furnaces, two blooming hammers, and one train of four sets of cogging rolls. The rest of the forge is utilised for steelwork. There is a fine-mill, rail-mill, plate-mill, sheet-mill, exceedingly well appointed in all ways. Moreover, a great workshop adjoins, with

	RESICZA	ROLLED METAL	CASTINGS
THOUSANDS	ANINA	—————	—————

DIAGRAMS 4 and 5.—Total Production of the Mills and Foundries at Resicza and Anina, 1882-1895.

Below 8, the vertical divisions are a thousand tons each;  
above 8, they are two thousand tons each.

a fine equipment of machine tools. The output is set forth in Diagram 4.

The production of pig at the Anina works of this company is set forth in Diagram 2. It may be mentioned that there are fifty-two coke ovens at Anina. Anina is chiefly a great foundry, and its work is set forth in Diagram 5. There is also an



horizontal, compound, and tandem, and nineteen boilers, with a total heating surface of 16,150 square feet. The water for power is brought by two canals, one  $1\frac{1}{4}$  mile long,  $34\frac{1}{2}$  feet wide, and 6 feet deep, the other about 460 yards long.

With this equipment the works can put out 14,000 tons of sheets yearly, from  $\frac{1}{16}$  to 2 inches in thickness, and up to  $39\frac{1}{8}$  feet long and 7 feet wide; the thin sheets being further treated. In addition, all sorts of rolled work is turned out up to 5-inch square section, the capacity in this direction being calculated at 15,000 to 18,000 tons a year.

The iron used is the best Hungarian charcoal pig, other materials being also for the most part Hungarian; the machinery being almost entirely of home manufacture.

There are employed at the works nine officials and 800 work-people, most of whom live in houses provided by the company. A doctor is attached to the works, and there are sickness, accident, life, and old age assurance funds, which are entirely or partially supported by the company. Telegraphic and telephonic communication is established to the railway station, the fire stations and throughout the works, which cover an area of five acres.

The company own a coal property in Sohl county with two seams, one of lignite and one of brown coal, and iron ore mines and quarries in Zips, giving occupation to two officials and eighty or ninety workpeople, who share in all the benefits accorded to those employed at the works.

It was not, however, left to Hungary alone to distinguish herself as an iron-producing country, for both Croatia and Slavonia, and Bosnia and the Herzegovina demonstrated that they too could contribute their quota to the world's supply of this useful metal.

In a corner of the Croatian and Slavonian pavilion there was an interesting exhibit of iron ore, limestone, charcoal, moulding sand, pig iron, castings, and other objects, besides drawings of mines and works; so similar in quality was the pig and castings, &c., to those in the other parts of the Exhibition, that I was at first inclined to think that they were identical, but closer inspection revealed differences, and further inquiry elicited a certain amount of information relating to the iron industry of Croatia





either to improve methods, &c., themselves, or test and adopt improvements due to others.

TABLE I.—*Data Relating to Hungarian Blast-Furnaces.*

Locality.	Height.		Diameter at Boshes.		Diameter at Crucible.		Diameter at Throat.		Capacity.	Annual Production.		Fuel.
	Ft.	In.	Ft.	In.	Ft.	In.	Ft.	In.		Cub. Ft.	Tons.	
Libet . . .	41	4	10	6	3	0	6	0	1,896	1,600	.....	
Govasdia . .	36	0	8	3	5	4	5	7	1,589	8,265	Beech charcoal.	
Vajda Hungad	65	8	18	8	7	3	15	1	10,170	40,000	Coke.	
" " "	...		...		See Fig.				...	...	Charcoal.	
Kalan . . .	40	0	14	6	4	0	11	9	4,132	10,000	Coke or charcoal.	
Rechitza . .	55	9	...		...		...		4,520	11,500	Charcoal.	
" " "	65	6	...		...		...		9,781	22,000	Coke.	
Bogsan . . .	44	0	11	5	4	6	8	4	2,422	4,820	.....	
Anina . . .	62	4	15	9	6	6	8	9	...	17,000	Coke and coal.	
" " "	62	4	15	9	6	6	8	9	...	17,000	Charcoal and coal.	
Liker . . .	...		17	9	8	10	14	11	8,427	...	Coke.	
Tiszolcz . .	43	8	12	2	4	2	9	2	3,172	3,930	Charcoal.	
" " "	40	10	13	6	4	8	8	9	3,531	...	Coke and charcoal.	







owner of it. Mr. Jeremiah Humphrey was the first maker of refined iron, and his process probably gave the first hint to Bessemer. It was owing to a dispute between Humphrey and the Crawshays that *Trevethick* ran, in front of the hall in which they were assembled that day, the first locomotive ever run on wheels in this country. Referring to the Workmen's Compensation Bill, he said most men would accept the principle of the Bill, but as it stood at present, instead of associating workmen and employers, and welding their interests together, it would tend to divide them more and more. In these days they heard much of the unearned increment, but when they had men like the Marquis of Bute, Lord Wimborne, and the Messrs. Crawshay investing their money for the benefit of tens of thousands of workmen, even Socialists would admit that they were doing their duty. The Dowlais Iron Company alone spent annually half a million in wages, and Lord Wimborne himself had to find a larger amount of capital than that to carry on the works successfully.

In the evening a very large number of guests were invited by the Reception Committee to meet the members of the Institute, and the ladies accompanying them, at a promenade concert in the Park Hall and grounds, which were beautifully illuminated. The programme of music which was provided was very highly appreciated and greatly enjoyed. The concert was followed by a dance, and this brought to an end a most enjoyable and in every way successful day.

On Friday morning, August 6, a special train, by invitation of the Great Western Railway Company, conveyed the members and a large number of other guests to Newport, where they were received by the Harbour Commissioners and the Mayor of Newport, and escorted to a steamer which was in readiness to take the party to the Docks. They were shown over the Alexandra and other docks, the whole of which are the property of Lord Tredegar and Sir George Elliot. The principal exports of the Alexandra Docks are coal and steel; the imports are iron ore, pig iron, timber, pitwood, and sleepers. The coal and coke shipped here in 1876 was somewhat less than half a million tons; in 1896 it was 3,275,512 tons, whilst the total exports in 1896 amounted to 3,563,698 tons. The number of vessels entering the docks in 1896 was 1888, of 1,665,933 net register tonnage. The shipments for the first half of 1897 were as follow:—Coal and coke, 1,695,445 tons; iron and steel, 47,718 tons. The imports during the same period were: Iron ore, 55,654 tons; pig iron, 2129 tons; pitwood, 28,360 tons; timber and deal, 18,036 tons. The Newport Dock and Railway Company dispensed



special train, kindly provided by the Rhymney Railway Company, conveyed the party to Caerphilly, where the Castle was visited. The party were entertained to tea in the old banqueting hall of the Castle by the kindness of the Local Reception Committee. On Thursday, August 1st, Cardiff Castle was graciously thrown open by the Marchioness of Eglborough for the lady visitors from 3 to 6 P.M.

NOTES ON WORKS VISITED.

DOWLAIS WORKS.

*Eleven Blast-Furnaces (six working and five idle).*

No. of Furnace.	Height of Furnace.	Diameter of Bosh.	Size of Hearth.				No. and Type of Stoves.
	Feet.	Ft. In.	Ft. In.		Ft. In.		
1	60	18 6	9 6	diam.	5 0	×	3 Cowper stoves.
3	70	18 6	9 6	„	7 0	×	3 „ „
9	60	17 6	7 6	„	5 0	×	3 Whitwell „
10	65	17 6	10 0	„	7 0	×	5 pipe „
11	80	18 6	9 6	„	7 6	×	3 Cowper „
19	60	18 0	9 6	„	6 4	×	4 Whitwell „

Nos. 8, 14, 15, 16, and 18 not working.

*Four Blast-Engines.*

No. of Engine.	Steam-Cylinder.				Blowing Cylinder.			Type.
	In.		Ft. In.		Ft.	Ft. In.		
1	55	diam.	×	13 0	12	×	12 0	Beam.
2	60	„	×	10 0	11	×	8 0	„
3	60	„	×	9 9	11	×	7 9	„
8	51	„	×	9 0	9	×	9 0	Horizontal.

*Coal-Washing Machine.*—Coppée and Luhrig's patent, designed to wash 1000 tons of coal per day. The coal is classified by screens and grading boxes into various sizes, and each size washed separately. The fine coal from 0 inch to  $\frac{3}{8}$  inch is washed in sixteen felspar bashes, and the coal above  $\frac{3}{8}$  inch is washed in ten ordinary bashes. The coal is of various qualities, bituminous and steam, which are mixed in various proportions according to the quality of coke required.

*Coke Ovens.*—224 Coppée type and 130 Welsh ovens.

*Cupolas at Cast-House.*—Three cupolas for melting iron for steel-works, 10 feet diameter of casing, and six tuyeres.

*Bessemer.*—New Bessemer pit, having two converters of 15 tons each capacity. Old Bessemer, having four converters, each of 10 tons capacity.

*Bessemer Blowing-Engines.*

Type of Engine.	Steam-Cylinder.		Blowing-Cylinders.	
	In.	Ft.	In.	Ft.
Vertical . . . .	48	× 5	54	× 5
Horizontal . . . .	36	× 5	48	× 5
Beam . . . . .	36½	× 7	48	× 7

*Siemens.*—Two furnaces of 25 tons each capacity, and six furnaces of 12 tons each capacity.

*Cogging Mills A, B, and C.*

Cog- ging.	Engines.					Centres of Mill.		Length of Roll.		
	Cylinder Diam.	Stroke.	Pres- sure.	Horse- Power.	Geared.					
	In.	Ft.	Lbs.			In.	Ft.	In.		
A	36	4	60	1500	3 to 1	37½	7	2		For Tin Bar Mill. In course of alteration. For Goat Mills.
B	36	4	80	1500	3½ to 1	37	7	8		
C	45	4	80	2500	2 to 1	37½	8	6		

*Rolling Mills at Old Works.*

	Rolling.	Type.	Engine.				Centres of Mill.
			Cylin- der.	Stroke.	Pres- sure.	Horse- Power.	
Goat Mill, right	Rails . . . .	2-high reversing . .	Ft. 48	Ft. In. 4 6	Lbs. 80	3,000	In. 25
Goat Mill, left	{ Rails and sleepers }	2-high reversing . .	54	5 0	80	4,000	28
Tin Bar Mill .	{ Tin bar and billets }	3-high non-reversing	42	4 0	80	1,200	23
Big Mill. . .	{ Light rails, billets, &c. }	2-high non-reversing	40	8 0	60	400	20

*Rolling Mills, &c., at Ifor Works.*—One forge with nineteen puddling furnaces. One light plate mill, 22-inch centres, 5 feet 10 inches roll. Two 12-inch bar mills. One 8-inch bar mill.

*Rail Finishing Department and Electrical Plant.*—All the straightening, drilling, ending machines, cold saws, &c., are worked by electrical power, and the lighting of this department is done with twenty-four arc lamps. The generating station for this consists of one compound engine, 13 inches and 23 inches by 2 feet stroke. Working pressure, 140 lbs. The dynamo will generate 150 horse-power at 230 volts.

The electrical power plant consists of one 10 horse-power, six 8 horse-power, three  $6\frac{1}{2}$  horse-power, fourteen 5 horse-power, one  $3\frac{1}{2}$  horse-power, and one 2 horse-power motors.

### DOWLAIS-CARDIFF WORKS.

*Blast-Engines.*—Four compound condensing blast-engines. High-pressure steam-cylinders, 36 inches diameter by 60 inches stroke. Low-pressure steam-cylinders, three are 62 inches and one 64 inches diameter by 60 inches stroke. Blast-cylinder, 88 inches diameter by 60 inches stroke. Each engine can blow 25,000 cubic feet a minute, and deliver blast at a pressure of from  $4\frac{1}{2}$  lbs. to 10 lbs. per square inch. Each engine, with a boiler pressure of 100 lbs., develops about 1200 horse-power.

*Pump-House.*—Seven compound condensing pumping engines, each having a capacity of 400 gallons per minute. Two compound condensing hoist pumps, with a capacity of 1500 gallons per minute. Three compound condensing boiler-feed pumps, working to a boiler pressure of 110 lbs. per square inch.

*Hydraulic and Electric Light House.*—One tandem compound condensing hydraulic pumping engine, having a capacity of 160 gallons per minute. One compound condensing hydraulic engine, delivering 90 gallons per minute. Two compound condensing hydraulic engines, each delivering 100 gallons per minute. The hydraulic pressure is 750 lbs. per square inch. There are also two tandem compound engines, each indicating 80 horse-power, giving electric light and power. The power of each dynamo is 230 amperes at 230 volts.

*Blast Engine-House.*—146 feet by 32 feet by 60 feet high. Capacity of top tank for tuyeres, 178,000 gallons. Capacity of tank on hydraulic engine-house, 90,000 gallons. Capacity of bottom tanks, 120,000 gallons.

*Boilers.*—Twelve steel boilers, 8 feet 6 inches diameter, 30 feet long, and about 250 horse-power each.

*Boiler Chimney.*—Height, 240 feet from Moor's level. Height, 278 feet from bottom of foundations. Inside diameter at top, 13 feet 6 inches. Capable of working twenty-four boilers.





50-ton square shaft traveller over the plate-mill, and a quick-speed electrical traveller over the plate-mill bank. The loading of the plates will be carried out by an electric traveller in course of erection. No. 1 plate-shear will cut plates up to  $1\frac{1}{4}$  inches thick, and No. 2 shear plates up to 2 inches thick. The shear-blades are on the same level as the mill-floor, so the plates are sheared without being lifted.

*Test-House.*—A machine for preparing test-pieces is driven by an electric motor. The tensile testing machine will test up to 100 tons, and there is a hydraulic machine for “bending” tests.

### DOWLAIS-CARDIFF COLLIERY.

This colliery is situated at Abercynon, upon the Taff Vale Railway, about 15 miles north of Cardiff.

Two pits have been sunk 153 feet apart, each 20 feet in diameter and 740 yards deep. Several seams of coal of excellent quality were passed through, the two seams opened upon being from 6 to 7 feet each thick. The colliery has only recently been opened out.

The present output is about 650 tons of coal per day, which will probably be increased to 2000 tons per day when the pits are fully developed.

*North Pit Winding Engine.*—Cylinders 42 inches in diameter. Stroke 7 feet. Conical drum, large diameter 32 feet, small diameter 17 feet.

*South Pit Winding Engine.*—Cylinders 36 inches in diameter by 6 feet stroke. Drum, plain cylindrical, 17 feet in diameter. The pithead framings are each 72 feet from the landing to the centre of the pithead pulleys. The pulleys are 18 feet in diameter. Cages 14 feet 6 inches long by 4 feet 6 inches wide, weighing five tons each, and carrying two trams on single deck tandem fashion. The carrying capacity of the trams is 2 tons each, with a gauge 3 feet 2 inches.

*Ventilating Fan, Schiele Type.*—21 feet in diameter, driven by a compound condensing engine. High-pressure cylinder 22 inches in diameter, low-pressure cylinder 36 inches in diameter. Stroke 4 feet 6 inches. Fly pulley 20 feet in diameter. Pulley on fan shaft 8 feet 6 inches in diameter. Belt three-ply leather 3 feet 6 inches wide. There is also an auxiliary non-condensing engine, cylinder 36 inches in diameter, stroke 4 feet 6 inches.

*Main Pumping Engine.*—This is of the Hawthorn-Davey type, with the two rods balancing each other. High-pressure cylinder, 45 inches



dust by compressed air and water. The arches of the bottom of the north pit will be 23 feet diameter in the clear, and in the south pit 20 feet diameter in the clear. The side walls are 6 feet thick and the arch rings 4 feet thick, all built with dressed native Pennant stone.

### THE BUTE DOCKS.

These docks are now famous throughout the world. They are 111 acres in extent, and will accommodate the largest vessels afloat. They are supplied with the most modern machinery for the discharging and loading of vessels, the greater portion being worked by hydraulic pressure. A working model showing the various appliances for loading and unloading was exhibited at the meeting by Sir William Lewis.

### THE PENARTH DOCK.

The length of the dock is now 2900 feet, with a basin of 400 feet in length, and a water area of dock and basin of 26 acres.

### MELINGRIFFITH TINPLATE WORKS.

Melingriffith Tinplate Works are situated within one mile of Llandaff Station, on the Taff Vale Railway, or four miles from Cardiff. The works consist of seven steam and four water-mills, capable of turning out 6500 boxes of 14 inches by 18 $\frac{3}{4}$  inches (124 sheets, 112 lbs.) per week, with sufficient pickling, annealing, cold rolling, and coating power to convert this quantity into finished tinplates, as well as the necessary smith's, carpenter's, and fitting shops. They are now the oldest works in the trade, and constitute one of the very few where mills are driven by water and steam-mills of 150 lbs. pressure. Weekly consumption of steel bars nearly 400 tons, and workpeople employed, 475. The works are connected with the Taff Vale Railway by means of a siding 1 $\frac{1}{2}$  miles in length, and also surrounded by the Glamorganshire Canal.

### THE CYFARTHFA IRON AND STEEL WORKS.

One of the old blast-furnaces bears the date of 1765; also the date of 1827, when it was rebuilt. They have been almost from the commencement in the possession of the same family—the Crawshays, of Cyfarthfa Castle and of Caversham Park—under whose fostering care and indomi-



The brickworks consist of two complete plants, each capable of making both red and fire bricks on the plastic system, at the nominal rate of 20,000 bricks per day. Besides the manufacture of these bricks, tuyeres, seats, stoppers and pipes are made for use in the Bessemer department; and bricks for lining the blast-furnaces, for the Cowper stove regenerators, and for the coke ovens, all of special size or form, are also made by machinery, effecting a great saving of labour as compared with hand-making. There are six circular brick-burning kilns, each capable of burning 30,000 9-inch bricks at a time. The kilns are on the down-draught principle, and each has its own chimney, and works independently of any of the others. A rectangular kiln on the same principle has been added for burning special and fancy bricks. Suitable materials for the manufacture of excellent bricks are obtained on the property. The brickworks are lighted by electricity, and the drying stoves are heated by the exhaust steam of the brickworks engine by day, and by that from the electric light engine by night. The steam for working the engines, which together develop some 220 indicated horse-power, is generated by the waste heat from the coke ovens, conveyed to the brickworks in pipes, well covered with asbestos to prevent radiation.

The coal-washery is a very efficient plant, and gives great satisfaction. It is on the jig system. It deals easily with over 500 tons per shift, and the mixing, sizing, and washing of the coal are all that can be desired. The loss of coal due to washing is under 5 cwt. per 100 tons, while the refuse is completely eliminated, reducing the ash in the coke to a minimum. A noteworthy feature of the plant, which otherwise possesses much in common with modern coal-washing plant, is the settling chamber, which dispenses with the usual settling ponds, with their attendant trouble and expense in cleaning out, enabling the water to be used over and over again, and to this is due the very small amount of waste. The nut and pea coals on leaving the washing machines pass through a screen perforated to allow the water to escape through to the settling chamber, and are elevated to a Carr's disintegrator, where they are reduced to a powder, and fall to the foot of a second elevator, where they meet the duff coal from the settling chamber, and the whole of the coals thus reduced to the required fineness are raised to extensive storage bunkers capable of holding about 600 tons of clean coal, fitted with distributing screws, by means of which the coal is taken to whichever part requires filling.

The arrangements at the coke ovens are very complete. The ovens are of the Coppée type in two banks of ninety each, and are fed with









supported on strong cast iron pillars and wrought iron girders, is a three-flued boiler by Davy Brothers, Sheffield. The waste heat from the furnace passes through the boiler twice, and afterwards upwards towards the chimney through a vertical feed-water heater. The boilers will be retained, but it is ultimately intended to adopt a type of vertical furnace here similar to that put down for No. 2 mill, the waste heat and gases from which will be utilised for use in the boilers.

No. 2 mill is being erected where stood the old Castle Rail Mill, and in its arrangements modern ideas and contrivances for minimising labour and increasing the output have been adopted, so far as the exigencies of existing buildings and machinery will permit, which, in some cases, require very considerable alteration and rearrangement. The rolling trains consist of a 36-inch cogging-mill, driven by a geared pair of horizontal reversing condensing engines, 42 inches diameter by 5 feet stroke, and a 27-inch roughing and finishing train, driven by a pair of horizontal reversing condensing engines, 50 inches diameter by 5 feet stroke. The cogging mill has a 6-inch lift of rolls, controlled by hydraulic balancing rams, and by a steam screwing-down gear. This makes the cogging-mill an almost universal mill, for besides supplying the rail-mill with bars of required sections, blooms, slabs, and billets of every practical size can also be turned out.

This mill is also provided with a hydraulic gear of the most approved type for turning or manipulating the ingot during its passage through the rolls. A powerful horizontal bloom shears is placed nearly half-way between the cogging-mill and the roughing-mill, and a subway is arranged for dealing with the crop ends, cobbles, &c., and a hydraulic crane also has been conveniently placed for serving this shears. The ingots are brought in from the Bessemer shop on bogies, drawn by a 3-foot gauge locomotive, and it is intended to strip the moulds in convenient contiguity to the soaking-pits.

The soaking-pits or vertical furnaces are served by cranes so arranged as to command the roads bringing in the ingots, and a line of live rollers running direct to the cogging-mill, so that the charging and drawing of the furnaces are thoroughly under control. The ingots are clogged to a bloom about 7 inches square, which, after treatment at the shears, will be long enough to roll into four, three, or two lengths of rails, either 30 feet, 40 feet, or 60 feet long, as may be required. This bloom is carried by live rollers to the roughing rolls, where, when roughed, it is turned over by means of a hydraulic apparatus to the finishing rolls, and thence to the hot saws by suitable draw-out roller gear. The required lengths



Under contiguous shedding to No. 1 rail shed is a sleeper plant, consisting of a steam lever-shears by Davy Brothers, for cutting hot bars into suitable lengths for sleepers, and a patent heating furnace, fed by steam power, one powerful hydraulic sleeper press, and two hydraulic punching presses, all by Davy Brothers. Adjoining the No. 2 mill are the merchant bar and guide mills, driven by an oscillating non-condensing vertical engine, 34 inch cylinder by 5 feet stroke. The merchant mill has three-high roughing and two-high finishing rolls, while the guide mill has three high-roughing and three high-finishing rolls. There are four heating furnaces. In close proximity to this mill are nine lathes for roll turning, which are driven by a vertical non-condensing engine, 26 inch cylinder by 30 inch stroke, and served by a 15-ton overhead travelling crane. In the lower forge is a 16-inch forge train, worked by a water-wheel 20 feet diameter by 10 feet wide, which also works a squeezer and shears. A 17-inch bar-mill, under the same roof, is driven by a water-wheel of the same dimensions, and both trains are served by some twenty-one puddling furnaces.

In the old upper forge, which is now idle, there is a large water-wheel  $36\frac{1}{2}$  feet diameter by 8 feet wide, which is remarkable in that it combines in itself the features of an over-shot, breast, and under-shot wheel, as the water was applied at three different points. This is considered an excellent specimen of the engineering of its day, and has turned out enormous quantities of work. In connection with the steel-mills Nos. 1 and 2, may be mentioned that they are provided with overhead travelling cranes dominating the whole span, and providing every facility for changing rolls, and every other similar requirement.

The engineering shops consist of fully equipped foundries, pattern-shop, machining and fitting shops, boiler and smiths' shops, carpenters' and waggon-building shops, and sawmills. The foundry proper is furnished with two steam 15-ton cranes and two hand-power cranes, two cupolas, two large air-furnaces, and a roll-casting pit, in which chill and other large rolls for the works are cast. The ingot mould foundry is also completely equipped for its operations, with overhead steam travelling crane, stoves, &c., and is placed adjacent to the remelting cupolas for the Bessemer department. The pattern-shop is fitted up with steam-power turning lathes, circular and band saws, hand-power mitreing shears; and the fitting shop is adequately furnished with suitable heavy and light tools for dealing with the many requirements of the works, and there is also a large locomotive repairing shop for the fifteen locomotives required to deal with the heavy traffic. The smithy



## BARRY DOCK.

The width of the entrance channel between the breakwater heads is 350 feet, and the length of that channel is 1500 feet. The width of gates opening on the basin, with an area of 7 acres, and on the dock (No. 1) with an area of 73 acres, is 80 feet, and the gates are worked by hydraulic cylinders.

A deep lock with 13 feet 7 inches of water on the cill at low water of spring tides has now been completed.

There are twenty-five staiths or tips for the shipment of coal, viz., twenty-one fixed, three movable, and one traversing. There are also thirty-one cranes of various kinds provided for the discharge of imports, &c.

	Tons.
Average shipment per week, last half-year . . . . .	119,783
Largest weekly shipment . . . . .	158,631
Largest daily shipment . . . . .	33,143
Largest quantity shipped in one hour at one tip . . . . .	490

THE BUTE SHIPBUILDING, ENGINEERING, AND DRY DOCK CO.,  
LIMITED, CARDIFF.

The above works and dry docks are situated just within the main entrance to the port, viz., Roath Basin. The docks are 600 feet long and 74 feet wide at bottom, and such large steamers as the *Knight Bachelor*, *Ranza*, and *Samoa*, which are the largest traders to the Bristol Channel, have been dry-docked in these docks. Vessels can be docked and undocked regardless of tides and without the aid of tugs, and are then in a position to proceed to either the Roath Basin, Roath Dock, or East Dock, for loading with the minimum of transporting. The dry docks are so constructed that the water can either be pumped out or run away into the Channel. The whole of the machinery is of the most modern type, thus enabling the Company to carry out repairs with economy and despatch.

THE CARDIFF CHANNEL DRY DOCKS.

The Cardiff Channel Dry Docks and Pontoon Co.'s property, situated outside the entrance to the Roath Basin, midway between Cardiff and Penarth, and adjoining the Bute Docks Co.'s large new import and export dock now under construction, is one of the features of the port of Cardiff. The dry dock, which is rapidly nearing completion, is expected to be opened during the first week in October next, and when finished,



number of ships and steamers repaired and docked last year was 441. The firm are builders of small steam-vessels up to 600 tons, and build their own engines and boilers. They have recently built several crafts for foreign account, besides a powerful screw tug for Messrs. W. & T. Jolliffe, of Liverpool.

The works are the oldest established of their kind in Newport. During Messrs. Mordey & Carney's time considerable improvements have been made. Within the past few years they have constructed a large modern dry dock. The company are also the proprietors of the Cardiff Slipways and Central Engineering Works, Cardiff, besides a large branch establishment at Barry Dock.

### THE GREAT WESTERN COLLIERY COMPANY.

The Great Western Colliery Company, Limited, have a taking of over 3000 acres of steam and house coal, situated at the southern end of the Rhondda Valley, say between the Hafod Ynysbwl and Pontypridd Stations of the Taff Vale Railway, and from which they are now working about 750,000 tons of steam-coal yearly.

At the Western Colliery, situated on the western side of the railway, they have two pits. The No. 1, or Hetty downcast shaft, is the principal one for raising coal, but a fair quantity is also brought to bank at the No. 2 upcast shaft. There is a recently erected compressed air engine for underground haulage, also 120 Coppée coke ovens.

The Tymawr Colliery is on the eastern side of the railway. The coal is raised from an old shaft which was deepened to cut the lower measures. There is here a very fine compressed air haulage plant, the steam-engines being compound condensing, with apparatus for re-cooling the condensing water.

At the Maritime Colliery, near Pontypridd, there are also a couple of pits. This colliery was only lately acquired, and is being developed chiefly with a view to the production of coking coal.

### POWELL DUFFRYN STEAM-COAL CO., LIMITED.

This Company possesses a large-sized coal-washery with 160 Coppée ovens. There are two pits winding coal from 440 and 530 yards, fitted up with air-compressing plant for underground haulage, and the generality of the machinery is of the most modern type. The underground pumping-engine forces 600 gallons per minute 530 yards vertical.





offices in the kingdom. The ground floor, which has a uniform height of nearly 21 feet, consists of a noble vestibule having a mean width of 24 feet, lined with encaustic tiles. Separated from the vestibule by a teak and plate-glass screen is the advertisement office, and at the rear of this are the stationery and typewriting departments, secretary's, cashier's, advertisement manager's, and accountant's rooms, and the clerks' office. The upper floors are approached from the vestibule by a hydraulic lift and a handsome teak staircase. The first floor is nearly 17 feet in height. Facing the street is the editor's room, behind which is the porter's office and the general manager's room. At the rear are the editorial offices and photo-etching department. The second floor also has a height of nearly 17 feet, and consists of the editor's private rooms in the front, and in the rear the stereotype foundry, linotype room, readers' room, &c. The linotype room contains fourteen machines, most of them duplex, and one headline machine, fitted with two distinct founts of matrices in each magazine. There is a second hydraulic lift at the rear of the building, intended for the conveyance of stereotype plates from the foundry to the machine-room in the basement, but also affording communication between every floor. In the basement are three powerful tubular boilers, a pair of compound engines, pumps for working the hydraulic lifts, two dynamos for supplying electric light to the buildings, and two Hoe presses. One of the latter is a double-width machine, from which can be printed a paper of any number of pages from four to sixteen, the latter at the rate of 12,000 per hour. The smaller machine will print a four-page paper at the rate of 24,000 per hour, or eight pages at the rate of 12,000 per hour.



guages. A welcome having been accorded to the Congress by Mr. E. von der Lancken, deputy-governor of Stockholm, the President read a report of the proceedings of the Association since the Zürich Congress. The following gentlemen were then elected Honorary Presidents of the Congress:—Mr. W. Ast (Austria), Mr. A. Greiner (Belgium), Professor H. J. Hannover (Denmark), Mr. Nyberg (Finland), Mr. T. Peters (Germany), Mr. Bennett H. Brough (England), Mr. E. Polonceau (France), Mr. H. Baucke (Holland), Mr. C. Banovits (Hungary), Mr. S. Fadda (Italy), Mr. A. Dutreux (Luxemburg), Mr. H. Krag (Norway), Mr. J. V. Mendes Guerreiro (Portugal), Professor N. Bebelubski (Russia), Colonel A. Mayanda (Spain), Mr. R. Åkerman (Sweden), Mr. A. Schrafl (Switzerland), and Mr. G. C. Henning (United States).

The meeting was then divided into two sections, one dealing with metals and the other with stone, cement, and other building materials. In the metallurgical section the first paper read was by Mr. Axel Wahlberg (Director of the Stockholm Testing Works), on the development of testing methods in Sweden. A lecture by Mr. F. Osmond on metallography as a method of testing was warmly applauded, and the numerous lantern slides illustrating the microscopic structure of metals attracted great interest. Mr. Ast and Mr. Barba read a paper on the resolution proposed by Mr. Schrödter at the Zürich Congress, that endeavours should be made to introduce international uniform specifications of the quality, testing, and acceptance of iron and steel materials of every description. In the discussion that ensued, Mr. Schrödter pointed out that most of Mr. Ast's propositions were not in accord with the views he had in his mind when two years previously he brought forward the proposition. The field of operations had been extended in such a manner as to render it difficult to arrive at a conclusion.

Mr. E. Polonceau then submitted a report on the divergencies between the resolutions arrived at by the previous International Congresses and by the French Commission on Methods of Testing.

Professor Wedding read a report on the establishment of an international laboratory for the chemistry of iron. The aim of such a laboratory would be to compare and to fix the degree of accuracy in the analytical methods employed, and to specify those which were worthy of recommendation in cases of controversy, whether for exact assays in technical laboratories, or for daily controlling the manufacture. The laboratory would in no way be occupied with commercial and technical analyses, nor with analyses made for third parties.

Thanks to the generosity of the Swiss Government, a suitably equipped building had been provided, and the salaries of the officers had been partially covered by voluntary subscriptions promised for ten years by the leading ironworks. Although the sum promised was not yet sufficient to carry out the programme in its entirety, it was sufficient to warrant a start being made.

A detailed report of the proceedings of the Congress is published in the official organ of the Association—*Baumaterialienkunde* (Stuttgart).

It was decided that the next Congress should be held in Paris in 1900, and the following gentlemen were elected additional members of the Executive Council,—Mr. R. A. Hadfield (Great Britain), Mr. Axel Wahlberg (Sweden), and Captain O. M. Carter (United States).

*O B I T U A R Y.*

GUILLERMO BOBRZYK, of Garrucha, Spain, died at Magdeburg in September 1897. He was a man of high professional standing as a mining engineer, and contributed largely to the development of the lead and iron mining industries of the provinces of Almeria, Murcia, and Granada. His interests were not confined to his professional work. He possessed great literary taste, and collected a unique library dealing with the Moorish dominion in Spain. He was elected a member of the Iron and Steel Institute in 1892.

WILLIAM DAVIES died at Sheffield on July 14, 1897. Born at Merthyr-Tydvil in 1836, he learnt the business of draughtsman and pattern-maker at the Ebbw Vale Works, where his father was employed as forge manager. On leaving the Ebbw Vale Works in 1862, his father became forge manager of the Millwall Works of Messrs. Hughes, and in 1864 Mr. Davies was appointed assistant manager, and on the death of his father he was appointed manager. After serving for a short time as manager of the Coatbridge Works of Messrs. Jackson, he became in 1871 connected with the firm of John Brown & Co., where he was identified with all the various changes in armour-plates during the past twenty-five years. He was obliged, in consequence of failing health, to retire from business, and his valuable services to the company were recognised by a substantial pension. He was elected a member of the Iron and Steel Institute in 1889.

BRUNO EHRHARDT died at Bockwa, near Zwickau, Saxony, on October 16, 1897. Born on April 11, 1836, at Oberrossau, he received his technical education at the Chemnitz and Dresden Technical Schools, and at the Freiberg School of Mines. On December 1, 1857, he received an appointment at the Königin Marienhütte at Cainsdorf, near Zwickau, at that time the only large ironworks in Saxony. At these works, to which he devoted his whole life, he rose from being foreman at the coke-ovens up all the steps of the ladder to the position of general



Lowe of Laurence Pountney Hill, E.C., which he joined on the retirement of the late Mr. James Bird, under whom he had been trained. The firm was well known, and enjoyed a large and important foreign connection. Mr. Lowe possessed an excellent technical knowledge of engineering matters, which was of great value in the management of the firm's extensive operations. He was a member of the Institution of Civil Engineers. He was an original member of the Iron and Steel Institute, and took a keen interest in its meetings, at which he was a constant attendant.

JOHN MALLABAND died at Sheffield on August 24, 1897, at the age of sixty-seven years. He left Coventry about the year 1857 and went to Sheffield, where he started as a moulder. He was appointed manager by the late Mr. Robert Hadfield on the establishment of the works now known as Hadfield's Steel Foundry, and afterwards became a director of Hadfield's Steel Foundry Company, Limited, a position he held at the time of his death. It was largely due to his great practical abilities that the company gained the high standing which they enjoy as manufacturers of steel castings. Mr. Mallaband was elected a member of the Iron and Steel Institute in 1889.

THOMAS REES MORGAN, of the well-known Morgan Engineering Company of Alliance, Ohio, died suddenly on September 6, 1897, at the age of sixty-three. Born in Wales, he left his native country for the United States in 1865, and three years later began business in Pittsburgh as a maker of steam-hammers and other special machinery. In 1871 he went to Alliance, and built the great works that made him famous. He was elected a member of the Iron and Steel Institute in 1882.

ARTHUR GRAEME OGILVIE died at his residence in St. John's Wood, London, on July 29, 1897, at the age of forty-seven. He was educated at Rugby and at Trinity College, Cambridge, graduating in the Natural Science tripos of that University in 1873. He then served a pupillage of three years to Sir George Elliot, Bart., and passed the examination qualifying him for a colliery manager's certificate. From 1878 he practised as a mining engineer in Westminster. He held a leading position in the South Wales district, having been chairman of the Powell-Duffryn Steam Coal Company for several years past, and in 1893 he was chairman of the South Wales and Monmouthshire Coal Owners' Association. He was an Associate Member of the Institution













**COLONIAL AND FOREIGN.****Colonial.**

Canadian Institute.  
Canadian Society of Civil Engineers.  
Department of Mines, Sydney.  
Department of Mines, Melbourne.  
Geological Survey of Canada.  
Geological Survey of India.  
Mining Society of Nova Scotia.  
Royal Society of New South Wales.

**United States.**

American Association for the Advancement of Science.  
American Institute of Mining Engineers.  
American Iron and Steel Association.  
American Society of Civil Engineers.  
American Society of Mechanical Engineers.  
Bureau of Statistics.  
Engineers' Society of Western Pennsylvania.  
Franklin Institute.  
Ordnance Office, War Department.  
School of Mines, Columbia College, New York.  
Smithsonian Institute.  
United States Geological Survey.

**Austria.**

K.k. geologisches Reichsanstalt.  
Oesterr. Ingenieur und Architekten-Verein.

**Belgium.**

Ministère de l'Interieur.

**France.**

Comité des Forges.  
"Revue Maritime." Ministère de la Marine.  
Société d'Encouragement pour l'Industrie Nationale.  
Société de l'Industrie Minérale.  
Société des Anciens Élèves des Écoles Nationales d'Arts et Métiers.  
Société des Ingénieurs Civils.  
Société Scientifique Industrielle de Marseille.

**Denmark.**

Tekniske Foreningen.

**Germany.**

Königliche Bergakademie in Freiberg.  
Königliche Technische Versuchsanstalt.  
Verein Deutscher Eisenhüttenleute. (Journal "Stahl und Eisen")  
Verein Deutscher Ingenieure.

Italy.

Reale Accademia dei Lincei.

Japan.

Department of Mines.

Sweden.

Jernkontoret.

## JOURNALS.

The following periodicals have been presented by their respective Editors :—

### UNITED KINGDOM.

- "Bimetallist."
- "British Trade Journal."
- "Coal and Iron."
- "Commerce."
- "Contract Journal."
- "Colliery Guardian."
- "Electrician."
- "Electrical Engineer."
- "Engineer."
- "Engineer and Iron Trades Advertiser."
- "Engineering."
- "Engineers' Gazette."
- "Hardwareman."
- "Hardware Trade Journal."
- "Industries and Iron."
- "Invention."
- "Iron and Steel Trades Journal."
- "Iron and Coal Trades Review."
- "Ironmonger."
- "Ironmongery."
- "Iron Trade Circular."
- "Marine Engineer."
- "Machinery Market."
- "Phillips' Monthly Register."
- "Plumber and Decorator."
- "Practical Engineer."
- "Railway Engineer."
- "Railway World."
- "Shipping World."
- "Statist."
- "Steamship."
- "The London Technical Education Gazette."
- "Tool and Machinery Register."
- "Transport."



SECTION II.

*NOTES ON THE  
PROGRESS OF THE HOME AND FOREIGN  
IRON AND STEEL INDUSTRIES.*

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In the preparation of these Notes the Editor has been assisted by E. J. BALL, Ph.D.,  
H. G. GRAVES, Assoc. R.S.M., and G. KAMENSKY, Assoc. R.S.M.



# IRON ORES.

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### I.—OCCURRENCE AND COMPOSITION.

**Formation of Ore Deposits.**—L. de Launay\* publishes an important contribution to the study of metalliferous deposits. The memoir extends to a hundred pages, and deals firstly with an attempt to arrive at a theoretical classification of metalliferous deposits, in which the nature and importance of veins of inclusion and of segregation are appreciated; secondly, with the action of surface changes; and lastly, with the application of the views propounded to various metals. The starting-point of every metalliferous deposit should, the author thinks, be sought in an internal metallic bath kept in a molten state by reducing actions in which carbon, hydrogen, and perhaps sulphur, take part. Examples more and more altered, more and more oxidised, are presented; firstly by meteorites, then by peridotites, and lastly by basic rocks. By an examination of such basic magmas, the study of ore deposits ought properly to begin, and it is of special interest to consider from this point of view the new class of deposits that the author proposes to add to the two classic categories of veins and beds. This constitutes a type less altered than the two classes mentioned, and comprises the deposits of inclusion and those of direct segregation, deposits that have remained in absolutely intimate relations with the basic rocks from which all the others are supposed to have been derived. Deep metallic baths of this kind appear to have given, by various methods of derivation, all the rocks forming the earth's crust and all the mineral deposits.

\* *Annales des Mines*, vol. xii. pp. 119-228.



tion, cleavage, joints produced by contraction, fissures, and faults. Numerous illustrations of these occurrences are given.

**Gallium in the Cleveland Iron Ore.**—W. N. Hartley and H. Ramage\* have found that the element gallium exists in the clay ironstone of the Cleveland district of Yorkshire and in the blast-furnace iron from Middlesbrough. In their second paper on this subject they give in detail the methods used for isolating this metal and determining the amount present. Fractional precipitations are employed throughout, together with spectrographic analysis of the various precipitates and gravimetric determination of the purified gallium sesquioxide. The various operations are described at considerable length, and for these the original paper must be consulted. In part the methods followed are those of Lecocq de Boisbaudran. Experiments on all the raw materials and products show that the gallium exists in the ore, and is concentrated in the metal. It was also found that indium existed in a Spanish manganese ore. Some other British iron ores, including Northampton ore, were found to contain gallium. The gallium in the Cleveland ore was determined after separation by a long series of fractional concentrations and precipitations, and the amount present is given as 0·003 per cent. An attempt, though not so complete, was made to determine the percentage in mixer metal, and the results were closely in accord. In conclusion, the authors state that this metal is the richest source of gallium known. Hitherto it has been obtained from a zinc blende from Bensburg on the Rhine, where it probably is present to the extent of one part in 50,000.

**Iron Ore in Cumberland.**—Oscar Curtz† gives an account of the occurrence of hæmatite in Cumberland. The ore, he shows, occurs in limestone in beds, in veins, and in masses. As typical illustrations of these three classes he describes:—(1) Parkside Mine; (2) Gillfoot Park, Winder Gill, and Birks Mines; (3) Hodbarrow and Kelton Mines. He deals fully with the methods employed, and gives complete analyses of typical ores, showing in the best grade 59·09 per cent. of iron and 0·0095 per cent. of phosphorus, and in the second grade 43·84 per cent. of iron and 0·0063 per cent. of phosphorus.

**Magnetite in Austria.**—F. Kretschmer‡ describes an interesting occurrence of magnetite in the Mitteljagd Forest, near Mähr-Altstadt.

\* *Proceedings of the Royal Society*, vol. lx. pp. 393–407.

† *Jernkontorets Annaler*, vol. lii. pp. 268–279.

‡ *Jahrbuch der k.k. geologischen Reichsanstalt*, vol. xlvii. pp. 54–55.



The secondary deposits are richer in iron, and contain disseminated true brown hæmatites. The surface of the deposits is often irregular, and they pass, too, irregularly into the underlying basalt. In contradistinction to the primary ore deposits, these secondary deposits scarcely ever outcrop, but are covered by diluvium. The chief points at which this ore is mined are in the neighbourhood of Grünberg. The ore is submitted to mechanical preparation in trommels and on rotating tables, by which it is separated from clay and lumps of basalt and bauxite. In this way a product is obtained which amounts to about 30 per cent. of the total weight of material raised from the mine. It contains about 45 per cent. of iron, 0·2 of phosphorus, and from 0·8 to 1·2 per cent. of manganese. Occasionally, by the aid of other methods of concentration, the percentage of iron is brought up to 50. The ore at present mined is mainly employed in making foundry pig iron at the Buderus Works, near Wetzlar and Giessen, and some is used in the Siegen district. The deposits, though small and low in iron, extend over a very wide area, and are very cheaply mined.

**Iron Ore in Corsica.**—Nentien \* publishes a detailed study of the mineral deposits of Corsica. The memoir covers sixty-five pages, and is accompanied by a map of the island. The deposits described are extremely varied. Anthracite coal is met with at Orsani, and lignite of Eocene age at several places. There is but one iron mine, that of Farinole and Olmeta, which has long lain idle. The ore is magnetite, occurring in lenticular masses in the Pre-Silurian serpentine that forms the two hills north of Farinole. Manganese, though not worked, is met with in amphibolic schists at several places.

**Iron Ore in Sardinia.**—At a meeting of the Natural History Society of Rhineland and Westphalia, Stockfleth,† read an exhaustive paper on the occurrence of minerals of economic value in the southwestern portion of the island of Sardinia. When, some months ago, it was announced that iron ore had been discovered in that district in considerable quantities, little attention was paid to the news. It was, it is true, recognised that argentiferous lead ores had been worked there since ancient times, and that the zinc-mining industry, started thirty years ago, is in a flourishing condition, but no mention had previously been made of the occurrence of abundant and pure iron ores. The

\* *Annales des Mines*, vol. xii. pp. 231–296.

† *Stahl und Eisen*, vol. xvii. pp. 534–538.













With regard to the metallurgical preparation of the poorer ores, to which reference has already been made, in addition to the ordinary washing process, calcination is also occasionally employed. This is effected in gas-heated shaft-furnaces, which yield daily about 120 tons of calcined ore from 140 tons of raw material. Producer gas is employed, about 60 lbs. of coal being required for every ton of calcined ore produced. Coke-oven or other waste gases are also employed. The selling price of the ore is referred to, and it is pointed out that the ore is frequently broken down before charging to pieces of from 0·5 to 1 inch in size, this being stated to cause a considerable saving in the coke required in the blast-furnace. The cost of mining is referred to, and in the case of the upper ten feet in soft hæmatite this is stated to amount to 40 or 50 cents a ton.

The limestone used in the blast-furnace contains usually 4 per cent. of silica, 1 per cent. of iron oxide and alumina, and 94·6 per cent. of calcium carbonate. Of late, dolomite has been frequently used instead of lime. It is stated to prove beneficial in the removal of sulphur. As a rule, it contains 1 to 1·5 per cent. of silica, 1 per cent. of iron oxide and alumina, 54 per cent. of calcium carbonate, and 43 per cent. of magnesium carbonate.

An illustrated description has been published\* of the occurrence of iron ores in the Southern United States.

The *Age of Steel*† publishes a series of photographs of typical iron ore deposits and limestone quarries in the famous Coosa Valley region of Alabama. They afford a remarkable illustration of the great natural advantages enjoyed by the iron-making interests of Alabama.

W. M. Brewer‡ gives a brief account of the mining industry in the Cartersville district of Georgia, which is adjacent to Cherokee county. Iron ore was at one time worked and smelted on the Etowah river, and near by ochre is still worked from a deposit covering about five acres and of considerable thickness. Manganese ore to the extent of a thousand tons annually is produced in this district.

**Magnetic Properties of Iron Ore.**—Specular iron ore is peculiarly interesting from the facility with which it lends itself to the study of a variety of physical properties depending upon crystalline structure. Some time ago, Bäckström studied the phenomena of thermal expansion,

\* *Iron and Coal Trades Review*, vol. lv. p. 343.

† Vol. lxxxii. No. 10, p. 22.

‡ *Engineering and Mining Journal*, vol. lxiii. p. 575.



**Recent Researches on Meteorites.**—According to S. B. Mirat,\* the analysis of a meteoric stone which fell at Madrid on February 10, 1896, gave the following results:—

SiO <sub>2</sub>	MgO.	Fe.	FeS.	Fe <sub>2</sub> O <sub>3</sub>	Al <sub>2</sub> O <sub>3</sub>	Ni.	CaO.	MnO <sub>2</sub>
58·86	15·95	7·75	7·23	5·11	2·36	1·30	0·51	0·08

Phosphorus, chromium, copper, sodium, potassium, lithium, and nitrogenous compounds, which amounted in all to 0·85 per cent., bring the total to 100. The specific gravity is 3·6189 at 15° C., and the hygroscopic moisture amounted to 0·2841 per cent.

H. Laspeyres† describes a new meteoric mineral which he names Kosmochlor, and also some stony enclosures of the Toluca meteorite, Mexico. On treatment of the oxidised surface of the Toluca meteorite with acid, an insoluble residue was obtained having a composition which, by calculation, shows the insoluble residue to have consisted of 2·45 per cent. of orthoclase, 25·26 per cent. of plagioclase, 37·40 per cent. of augite, and 34·89 per cent. of quartz. The plagioclase consists of a mixture of 3 molecules of anorthite with 4 of albite, and is therefore similar to that found by Tschermak in the Gopalpur meteorite. In the solution was found some tin, no phosphoric acid, iron, aluminium, calcium, potassium, sodium, traces of nickel, and no traces even of chromium or zirconium.

Kosmochlor the author names a mineral which was also present in this meteorite, and insoluble in all acids. On fusion with nitre it passes into solution, and can afterwards be dissolved in water, yielding a colourless solution. Analysis showed it to have the following percentage composition:—

SiO <sub>2</sub>	Al <sub>2</sub> O <sub>3</sub>	Cr <sub>2</sub> O <sub>3</sub>	Fe <sub>2</sub> O <sub>3</sub>	CaO.	MgO.
32	9	39	9	6	5

The insoluble residue, consisting mainly of this mineral, had the specific gravity 3·158. The hardness is 5–6, and it is infusible. The author describes the mineralogical properties of this mineral in detail.

According to E. W. Cohen,‡ the meteoric iron from Locust Grove, North Carolina, weighing 23 lbs., was found July 29, 1857, and was kept at a house in Georgia until 1895. A bright meteor was seen in the locality on July 26, 1857, but the very thin coating of rust on the surface of the iron is probably more than would have been formed in three days. The structure is granular, with an absence of octahedral and twin

\* *Bulletin de la Société Chimique*, vol. xv. p. 1070.

† *Zeitschrift für Krystallographie und Mineralogie*, vol. xvii. p. 586.

‡ *Sitzungsberichte der Berliner Akademie*, 1897, pp. 76–81.



the etched surface, but are visible as an oriented sheen. On the etched surfaces of the kamacite individuals are the so-called file markings, together with systems of fine raised lines, called “Bendego lines,” which are apparently due to lamellar twining (parallel to the faces of the hexakisoctahedron [421]), as are the Neumann lines of hexahedral irons. Analysis of the bulk of the iron, which represents almost pure kamacite, gave I. (by Dafert), and a partial analysis by G. Florence is given under II. This agrees with the formula,  $\text{Fe}_{14}\text{Ni}$ , for kamacite. The troilite gave the results under III. (also a trace of silica). The residue probably consists of daubréelite and schreibersite. Cohenite is abundant, and is seen on the cut surface as embroidery-like patches. Measurements given by E. Hussak of the imperfect crystals show them to be isometric: specific gravity, 6.1805; analysis IV., by Dafert, after deducting 5.72 per cent. of schreibersite. The schreibersite and rhabdite gave analysis V. (also a trace of tin); measurements are given of the tetragonal rhabdite needles. Analyses were made of another phosphide of iron and nickel of uncertain nature, which remains as a black powder when the iron is dissolved in dilute acid. Some chromite, rich in crystal faces, hypersthene, and “magnetic globules” are also present. Carbon was shown to be absent in the gas evolved when the iron is dissolved in dilute acid.

		Fe.	Ni. Co.	Cu.	P.	C.	S.	Insol.	Total.
I.	. .	93.06	6.83	...	trace	...	...	0.38	100.22
II.	. .	...	6.36 0.79	0.0045	...	...	...	...	...
III.	. .	62.51	trace trace	...	...	...	33.24	5.26	101.01
IV.	. .	90.16	3.62	...	trace	6.39	...	...	100.17
V.	. .	52.42	33.51	0.25	15.09	...	...	...	101.27

R. C. Hills \* describes the meteorite recently found in the foothills of the Oscura mountains in Socorro county, New Mexico. Three irregular specimens, weighing  $1\frac{1}{4}$ ,  $3\frac{1}{4}$ , and  $3\frac{1}{2}$  lbs. were found. Analysis showed :—

Fe.	Ni.	Co.	P.	C.	Total.
90.79	7.66	0.57	0.27	0.07	99.36

Lieutenant Peary † has brought back the Cape York meteorite from the Arctic regions. It is variously said to weigh from 70 to 100 tons.

\* Paper read before the Colorado Scientific Society, April 1897, through the *Engineering and Mining Journal*, vol. lxiii. p. 382.  
† *Daily Graphic*, October 16, 1897; *Industries and Iron*, vol. xxiii. p. 337.





It appears to be braunite or hausmannite. The ore occurs in nodules, in schist and argillite, and could easily be quarried.

**Manganese Ore in Java.**—Pyrolusite is found at two places in the Joguia province, near Wada, and in the Keliripan mountains. Here a bed of the ore is mined varying from 0·5 to 1 yard in thickness. The ore is met with at various other places.\*

**Manganese Ore in the United States.**—In Colorado, Michigan, and Wisconsin, manganiferous iron ore is produced, that of the latter two States assaying 4 to 10 per cent. of manganese, whilst the Colorado ore contains 25 to 30 per cent. In New Jersey the product is chiefly franklinite residuum from the zinc furnaces. This material is smelted to spiegeleisen at three works which produced 12,403 tons in 1896. Other States produce chiefly pyrolusite. The Colombian, Russian, and other deposits are also shortly described.†

Manganese ore mining, according to W. M. Brewer,‡ has been carried on in Georgia for nearly fifty years, and up to 1896, 66,318 tons have been produced. The principal deposits worked are in Bartow and Floyd counties, at the Cartersville and Cave Spring districts, but ore is also found in Cartoosa county. Ore is usually prepared for market by screening instead of washing. Workings are usually open cuts, and are not on a large scale. The ore is found in pockets, and contains 44 per cent. of manganese on an average.

C. Catlett§ describes the manganese ore deposits which attain their greatest development along the western base of the Blue Ridge in Virginia, in a well-defined belt, a short distance above the Potsdam Sandstone. The manganese ores often pass into iron ores, and are persistent over 150 miles. The ore is mostly psilomelane in small nodular forms, or concretionary layers, and it occurs in beds of clay, which average four feet in thickness at Elkton. Analyses show:—

Silica	.	.	.	15·00	10·60	12·30	5·25	3·25
Iron	.	.	.	2·80	1·45	1·45	11·30	0·97
Phosphorus	.	.	.	0·114	0·116	0·125	0·196	0·10
Manganese	.	.	.	42·61	47·06	46·59	44·56	47·37

Two forms of secondary deposits are also found, one caused by washing down, and the other by solution and redeposition.

\* *Oesterreichische Zeitschrift für Berg- und Hüttenwesen*, vol. xlv. p. 418.

† *The Mineral Industry*, vol. v. pp. 415–419.

‡ Paper read before the Alabama Industrial and Scientific Society, through the *American Manufacturer*, vol. lx. p. 440.

§ *Engineering and Mining Journal*, vol. lxiv. pp. 156–157.







first cut out by driving a wide drift just under the sand, and supporting this drift by saddle-back timbering, which becomes the roof of the room. This roof timber is put in by driving from sub-drifts on the same level, thereby avoiding the hoisting of timbers. The rooms could be started from the tops of raises, if necessary. After the roof is thus securely supported, the ore is stoped underhand, through the raises, to the drift in the centre of the bottom of the room, where it is run into the cars and trammed to the shaft. The sides of the room are left unsupported; and the doubtful part of the experiment was whether these sides would stand. A number of rooms have already been mined in this way, without any trouble whatever; and, at least for the Fayal deposit, the experiment seems to be successful. The shaft is sunk in ore as close to the rock as possible, at an angle of  $66^{\circ}$  with the horizontal. Underground ore pockets are being generally adopted, and make tramming and hoisting independent of each other for a short time. The tramming is done by hand in the sub-drifts, but for long tramming on the main level mules are used, and have been found to reduce the cost materially. A special feature of the Fayal Mine is the use of "timber slides" for getting timber into the mine. These slides are made by putting up raises to the surface, 5 feet by 5 feet in section, and equipping them with skidways, down which the timber is allowed to slide. The skidways are curved at the bottom, to diminish the velocity of the timber. The angle of the first slide was  $45^{\circ}$ ; but the later ones were put at  $38^{\circ}$ , which is considered to be about the best angle. The men are made to travel in and out of the mine through inclined raises specially prepared for them, so as to lessen the chances of fire in the main shaft.

The Genoa Mine, which is just being developed, is also described briefly, and also the group of mines at Hibbing. The author then discusses the relative values of underground roads laid out on the diagonal and rectangular plans. The former is better for tramming, and the latter for support. Possibly a combination would be preferable, although it has not been tried. Another difference is the method of handling square-set rooms after they are completed. In one system, the rooms are caved by blasting in the roof and timbering, whilst in the other they are filled from the surface through raises. The former causes loss of pillars, and although rooming is economical in first cost, the remaining ore is not readily extracted. Other points of difference are also discussed. Mining on the Vermilion range has reached a fixed system, but no company appears to be satisfied with the methods on the Mesabi range.



raised 50 feet per minute in regular work. It is generally better to increase the speed than the load, as small buckets can be handled more easily. Light steel buckets weigh 200 to 300 lbs., and steel rope,  $\frac{1}{2}$  to  $\frac{5}{8}$  inch diameter, weighing 0·35 to 0·60 lbs. per foot, is used. In Mexico "malacates" or mule-whims, with overhead drums of considerable size, are employed, being built for use with eight to twelve mules.

**Mine Shafts.**—At the Engineering Congress of the Institution of Civil Engineers, Bennett H. Brough \* discussed the future development of deep-level mining in the United Kingdom. In his paper he advocated the use of shafts of circular section lined with iron in metalliferous mines. W. Thomas also dealt with the prospects of deep mining in Cornwall.

**Underground Temperature.**—W. Hallock † gives the particulars of underground temperature determinations at Wheeling, Western Virginia, and at Pittsburgh, Pennsylvania. The well at Wheeling is 4500 feet deep, 4 $\frac{7}{8}$  inches in diameter, and dry. The strata dip only 50 feet per mile, and are mostly of shale. The temperature near the bottom is 110·15° F., and the rise is 1° F. for 80 to 90 feet in the upper part and 1° F. for 60 feet nearer the bottom. When plotted, it is seen that the rise shows a nearly uniform curve. Two years later the hole had filled with water, and observations to a depth of 3200 feet showed that the temperatures were practically unaltered. There did not appear to be any water or air circulation in the boring. At Pittsburgh, in February 1897, a well had been sunk to a depth of 5386 feet, with a diameter of 6 $\frac{1}{8}$  inches. The temperature at the bottom was 127° F., giving almost identical results with the Wheeling well. Temperature readings made at 2250 and 2350 feet above and below a feeder of gas showed a cooling due to gas expansion of 14° F.

According to Libert, ‡ experiments made at the Sainte-Henriette shaft show that there is no regular increase of temperature with increasing depth, but that at first it increases slowly and subsequently with greater rapidity. The shaft is 3773 feet deep. For the first 650 yards the temperature increases 1° C. for every 98 to 115 feet, and from 650 yards downwards 1° C. for every 76 to 79 feet. These results are not identical with those observed at the deep bore-hole at Paruschowitz.

\* *Minutes of Proceedings of the Institution of Civil Engineers*, vol. cxxx. p. 201.

† *School of Mines Quarterly*, vol. xviii. pp. 148-153.

‡ *Annales des Mines de Belgique*, vol. ii. Part I.





An illustrated description has appeared\* of the François air compressor and rock drills shown at the Brussels Exhibition.

At the visit to the Carn Brea Mine made by the Cornish scientific societies, at their fifth annual joint meeting, experiments were made with rock-drills, different air pressures being employed. In five minutes, with a pressure of 40 lbs. to the inch, the drill pierced 20 inches of good granite; with 60 lbs. pressure, 36 inches of granite was pierced in the same time, and with 80 lbs. as much as 54 inches. The higher pressure therefore gave the best results.†

**A Mine Dam.**—W. Kelly ‡ describes the construction of a dam built in an exploring drift 6 feet wide and  $7\frac{1}{2}$  feet high, to cut off a feeder of water giving about 370 gallons per minute. The sides and roof were sheared back, and an arched masonry dam of stone laid in cement was put in, forming a taper plug 10 feet long and  $13\frac{1}{2}$  by  $12\frac{3}{4}$  feet in cross section at the back. As this leaked, a 22-inch brick wall was put in 26 inches behind the masonry, and the intervening space filled with concrete. Manure was spread over the back of this wall, and the dam was rendered watertight. A 20-inch manhole pipe and a 5-inch water pipe was laid in. The pressure rose to 277 lbs. per square foot, and the leakage amounted to  $2\frac{1}{2}$  gallons per minute. The cost and the details of increase of pressure are given.

**Pumping Plant at the Low Field Mine.**—Illustrations have appeared§ of a large pumping plant recently erected at the Low Field iron ore mines, near Ulverston. The engine is of the Davey differential type, with high-pressure cylinder 45 inches and low-pressure 80 inches in diameter. The shaft is inclined at  $42^\circ$ , and the length is 1150 feet on the incline, the vertical rise being 735 feet. Two thousand gallons are raised per minute. The main pump is of the single-acting plunger type, connected to the engine by a bell-crank and spear-rods. To equalise the delivery on the indoor and outdoor strokes a subsidiary hollow stationary ram, 17 inches in diameter, is provided. It is connected to a branch on the delivery main, and its casing is movable, being attached to the spears. These are built up of four 11-inch square rods, and carried on cast-iron rollers. The main plunger is  $30\frac{1}{2}$  inches

\* *Engineering*, vol. lxiv. pp. 289 and 294. † *The Cornishman*, September 30, 1897.

‡ *Transactions of the American Institute of Mining Engineers*, Lake Superior Meeting, July 1897 (advance proof).

§ *Engineer*, vol. lxxxiv. pp. 110, 118.



**Mining Law.**—H. D. Hoskold \* gives some notes on foreign mining laws and adequate areas for mining concessions. In Latin countries the laws are mostly codified, and especial reference is made to the code in force in the Argentine Republic. The dimensions for concessions in that country are given as about 170 and 258 acres for iron ore and coal respectively, and it is held that the former is too great and the latter too small.

An exhaustive memoir has been published by L. Michel † on the relations between the landowners and the mine owners with regard to the inconvenience arising from the use of surface waters.

Leon Michel has published a valuable guide to mining legislation. The subject is dealt with in nine chapters, namely—(1.) Introduction; (2.) Prospecting; (3.) Concessions; (4.) Royalties; (5.) Mine inspection; (6.) Quarries; (7.) Mining law in the French colonies; (8.) Foreign mining law; (9.) Special laws dealing with salt mines, mineral waters, steam-boilers in sanitary works. The volume covers 684 pages.

**First Aid in Mining Accidents.**—G. W. King ‡ deals with some of the methods to be employed in giving first aid in the case of mining accidents. The several kinds of splints to be used for broken bones are indicated, and the ways of moving the patient are described. Means for arresting hæmorrhage are referred to, and also for counteracting asphyxia. Illustrations of the methods are appended.

**Iron Ore Shipment.**—J. R. Oldham § gives some particulars of ship-building and transportation on the great American lakes. Illustrations of some of the large steamers for carrying ore are appended. A table has been published || showing dimensions and particulars of the ore docks on these lakes. Amongst the details are length, width, height, number and capacity of pockets, angle of the bottom of the pockets, and length of spouts. The storage capacity amounts to 617,250 tons.

H. V. Winchell ¶ gives some photographic views of the docks and ore pockets at Two Harbours, Minnesota.

\* *Transactions of the Federated Institution of Mining Engineers*, vol. xiii. pp. 160-173.

† *Bulletin de la Société de l'Industrie Minérale*, vol. x. pp. 725-773.

‡ *Engineering and Mining Journal*, vol. lxiv. pp. 245-247.

§ *Cassier's Magazine*, vol. xii. pp. 499-512.

¶ *Iron Age*, vol. lx., No. 6, p. 12; *Transactions of the American Institute of Mining Engineers*, Lake Superior Meeting (advance proof).

¶ *Engineering Magazine*, vol. xiii. pp. 884-895.



III.—MECHANICAL PREPARATION.

**Magnetic Concentration of Iron Ore.**—Discussing the recent progress in ore dressing, R. H. Richards \* describes the magnetic concentration of the soft Clinton red fossiliferous iron ore. The machine used was the Wetherill magnetic concentrator of the inclined pattern. The ore treated was crushed through 15-mesh, and that portion which rested on 40-mesh was used for magnetic concentration. The portion which passed through 40-mesh contained 49·4 per cent. of iron, and was considered sufficiently rich. The material through 15 on 40-mesh was subjected to three consecutive treatments—with 10, with 8, and with 6 ampères respectively. The heads of the 10 ampères went to the 8. The heads of the 8 ampères went to the 6. The tailings of the 8 and 6 ampère treatments are called final middlings, and the tailings of the 10 ampère treatment are called final tailings in the table.

	Weight.	Iron.	Insoluble.
	Per Cent.	Per Cent.	Per Cent.
Raw ore . . . . .	100·0	39·20	40·16
10 ampère . . . . .	59·3	54·10	18·80
8 ampère . . . . .	55·0	54·10	18·70
6 ampère . . . . .	52·4	56·40	17·10
Middlings . . . . .	6·9	38·85	41·35
Tailings . . . . .	40·7	16·70	74·10

The shrinkage in weight by the 8 and 6 ampère treatments lowered the value more than the increased percentage of iron gained, and hence it was decided that the single 10-ampère treatment was the best commercial method. The hard Clinton ore was treated with almost similar results.

**The Edison Magnetic Concentrating Plant.**—An illustrated description † has appeared of the magnetic concentration plant at Edison, which presents many novel features in the crushers and arrangement of plant. The whole of the run of the mine is crushed down without intermediate screening to pass a fourteen mesh sieve before it is treated magnetically, very large crushing rolls being used in the first instance, and subsequently three-high rolls of a type somewhat similar to those used in certain flour mills.

\* *The Mineral Industry*, vol. v. pp. 705-732.  
† *Iron Age*, vol. lx. No. 18, pp. 1-8.









	Per Cent.
Iron . . . . .	67 to 68
Silica . . . . .	2 to 3
Alumina . . . . .	0·4 to 0·8
Manganese . . . . .	0·05 to 0·10
Lime, magnesia, and sulphur . . . . .	trace
Phosphorus . . . . .	0·028 to 0·033
Resinous binder . . . . .	0·75
Moisture . . . . .	none

A blast-furnace test made with 25 to 100 per cent. of these briquettes, and lasting a week, has been made. The yield of iron was increased, and the consumption of flux and fuel diminished.



	1.	2.	3.	4.	5.	6.
Moisture . . . . .	0·47	1·36	...	...	...	3·75
Silica . . . . .	46·61	63·26	46·88	71·81	56·41	61·00
Alumina . . . . .	37·20	24·72	35·42	15·09	26·37	35·00
Ferric oxide . . . . .	0·15	0·43	1·74 <sub>a</sub>	1·75 <sub>a</sub>	...	0·25
Lime . . . . .	0·44	0·30	0·44	0·14	0·29	...
Magnesia . . . . .	0·25	0·13	0·20	0·05	0·20	...
Alkalies . . . . .	1·23	trace	1·19	1·02	1·55	...
Water . . . . .	13·65	8·63	14·10 <sub>b</sub>	10·14 <sub>b</sub>	14·66 <sub>b</sub>	...
Organic matter . . . . .	...	0·40	...	...	...	...
Titanic acid . . . . .	...	0·68	...	...	...	...
	100·00	99·91	99·97	100·00	99·48	100·00
Total fluxes . . . . .	2·07	0·86	3·57	2·96	2·04	...

1. Edgemont, Jefferson County. 2. Pueblo, Pueblo County. 3. Golden, Jefferson County. 4. Crucible clay, Golden, Jefferson County. 5. Kaolin, Golden, Jefferson County. 6. Pueblo, Pueblo County. *a.* Determined as ferrous oxide. *b.* This includes moisture.

**Fireclay in Missouri.**—C. R. Keyes\* gives some notes on the clays of Missouri, and adds the following analyses of fireclays worked in the State :—

Specific gravity . . . . .	2·47	2·13	2·45	2·43
Combined silica . . . . .	31·39	26·03	43·56	42·60
Free silica . . . . .	29·38	37·25		
Alumina . . . . .	23·56	21·16	41·48	41·88
Combined water . . . . .	9·25	8·94	14·05	14·00
Titanic acid . . . . .	0·96	1·07	...	...
Ferric oxide . . . . .	4·69	1·81	0·35	0·62
Ferrous oxide . . . . .	0·47	0·82	...	...
Lime . . . . .	0·55	0·61	0·45	0·28
Magnesia . . . . .	0·15	0·30	...	0·20
Potash . . . . .	0·92	0·51	0·20	0·54
Soda . . . . .	0·08	...		
Sulphur . . . . .	0·09	0·12	...	...
Sulphuric acid . . . . .	0·35	0·56	...	...
Total . . . . .	101·84	99·18	100·99	100·12

The first is a plastic fireclay from the Cheltenham seam in St. Louis county, and the second is the washed pot-clay of the same seam. The others are non-plastic or “flint” clays from Warren and Franklin counties. Fireclays are extensively worked in the State.

**The Origin of Dolomite.**—R. Hasselblatt† observes that from a consideration of the different occurrences of dolomite in the Caucasus

\* *The Mineral Industry*, vol. v. pp. 131–133.  
† *Chemiker Zeitung*, vol. xxi. p. 714.



**Hungarian Magnesite.**—Near Jolsvar, in Hungary, there exist deposits of magnesite belonging to a Budapest company. At present only the raw magnesite is being produced. Analysis gave the following results :—

MgCO <sub>3</sub> .	CaCO <sub>3</sub> .	FeO.	Al <sub>2</sub> O <sub>3</sub> .	SiO <sub>2</sub> .
94·8	0·1	3·2	1·1	0·8

It is intended to produce from this magnesite bricks as well as other products.\*

**Bauxite.**—No change of any import took place in the bauxite industry during 1896.†

F. Laur‡ describes the extraction of aluminates from bauxite. The method of manufacture comprises nine principal operations—(1) Comminution of the bauxite; (2) mixing with carbonate of soda; (3) formation of crude aluminate in the furnace; (4) washing the crude aluminate; (5) desiccation of the ochre residue and formation of liquors of soluble aluminates; (6) carbonation of the aluminate liquors; (7) separation of the alumina by exposure to the air; (8) drying the alumina; and (9) treatment of the carbonate of soda liquors.

A. Liebrich§ discusses the formation of bauxite.

**Graphite.**—Graphite to the amount of about 13,000 metric tons was produced during 1895 in Bohemia, chiefly from the deposits at Schwarzbach and Mugrau, whilst Upper Styria, Moravia, and the Duchy of Austria made up this to a total of 28,443 tons in 1895. In the same year Ceylon yielded 13,711 tons, Canada 199 tons, Germany 3751 tons, Great Britain 41 tons, Italy 2657 tons, and the United States 349 tons—making a total of 48,973 tons. The American graphite came from Ticonderoga and from Rhode Island, the former being pure and the latter impure, one mine yielding graphite containing 40 to 65 per cent. of carbon.||

F. Kretschmer¶ gives a detailed description of the graphite deposits of Mährisch-Altstadt.

\* *Oesterreichische Zeitschrift für Berg- und Hüttenwesen*, vol. xlv. p. 371 and p. 400.

† *The Mineral Industry*, vol. v. pp. 50–51.

‡ *Bulletin de la Société de l'Industrie Minérale*, vol. x. pp. 823–853.

§ *Zeitschrift für praktische Geologie*, 1897, pp. 212–214.

|| *The Mineral Industry*, vol. v. p. 325.

¶ *Jahrbuch der k.k. geologischen Reichsanstalt*, vol. xlvii. pp 21–56.



FUEL.

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I.—CALORIFIC VALUE.

**Calorimetric Measurements.**—L. C. Wolff\* discusses the question of calorimetric measurements. The empirical formulæ are first dealt with, and the author observes that the following has been adopted by the Verein deutscher Ingenieure and the International Verband der Dampfkessel-Ueberwachungsvereine, and is generally known as the “Verbands” Formula. In this formula 600 calories are subtracted for every kilogramme of hygroscopic water (W) which is evaporated in the fire and passes into the stack. The formula is as follows :—

Calorific power = 8000 C + 29,000  $\left( H - \frac{O}{8} \right)$  + 2500 S - 600 W.

The variations existing between the actual calorimetric measurements and the values as determined from analysis by the Dulong formula are as follows :—

	Per Cent.
Coal . . . . . plus or minus	2
Brown coal . . . . . „ „	5
Peat . . . . . „ „	8
Wood . . . . . „ „	12

In the case of pure cellulose, the Dulong formula only shows 3552 calories, while from actual determination it is found to amount to as much as 3855 calories, a difference of 7·9 per cent.

Dealing next with actual calorimetric measurements, the author

\* *Zeitschrift des Vereines deutscher Ingenieure*, vol. xli. pp. 763-768.





walls of the chamber itself are about 1 millimetre thick, and are gold-plated inside. A platinum crucible, with a hole in the centre of the bottom, is slipped over the end of the supply tube in the centre of the combustion chamber. At about half its height the crucible is divided horizontally by a removable disc of platinum. This disc has a great number of fine holes near its edge, but it is not perforated near the centre. Upon the centre of this plate the sample of coal to be burned is placed. A tight cover perforated with many fine holes is made of platinum somewhat thinner than the crucible walls. The upper parts of the crucible walls are perforated with fine holes. A fine platinum wire heated by a current serves as a fuse. It is insulated from the crucible by mica washers, and ends in stout terminals in the walls of the combustion chambers. These are insulated by mica and leather washers. The manipulation of the apparatus is described.

Baron H. von Jüptner\* again discusses the determination of the calorific power of coals by means of the Mahler calorimeter, and by using Jüptner's empiric formula. He deals at length with a paper by N. W. Lord and F. Haas, whose results are tabulated. Baron von Jüptner has already described a simple and rapid method for the determination of the calorific value of a coal, and this he again states as follows:—Find the percentage of moisture,  $W$ , in the coal; the yield of volatile matters,  $G$ ; the fixed carbon-coke,  $K$ , and the percentage of ash,  $A$ , in the crucible; and the amount of oxygen  $S$  required, by the Berthier method. The calculation is then as follows:—For the combustion of the fixed carbon is required the oxygen quantity  $S' = \frac{8}{3}K$ ; for the combustion of the volatile products the quantity of oxygen  $S'' = S - S' = S - \frac{8}{3}K$ ; the ratio of the oxygen required by the volatile matters to that required by the fixed carbon is—

$$\frac{S''}{S'} = \frac{S - \frac{8}{3}K}{\frac{8}{3}K} = \frac{\frac{3}{8}S - K}{K}$$

Placing the calorific power of the coke carbon at 8000 instead of the number 7630 formerly proposed, and taking  $C$  as representing the variable calorific power of the volatile products of distillation, the calorific power of a coal is represented by the formula:—

$$p = 80 K + C \frac{S''}{100}.$$

---

\* *Oesterreichische Zeitschrift für Berg- und Hüttenwesen*, vol. xlv. pp. 457–460.



table has been computed showing the cost of corn per bushel to equal that of coal selling at different prices.

An acre of land will produce from 40 to 80 bushels of corn, which if burned will yield 22,512,000 to 45,024,000 heat units. Since a ton of good coal will yield 20,000,000 to 26,000,000 heat units, it follows that an acre of ground is capable each year of producing fuel which is equal to from 0·87 or 1·28 to 1·74 or 2·56 tons of coal. The stalk will probably increase this amount by one-fourth.

Kaestner\* deals with the preparation and combustion of brown coal. All dry or wet-pressed brown coal briquettes, when properly used, are suitable, he observes, for house or works use. If the raw brown coal is to be burnt on a flat fire-grate, its size, he states, should be from that of "hens' eggs" to a "child's head" size. This is not the right way to burn brown coal though. He illustrates a suitable form of step grate, the success or failure depending on the angle. A step grate which will do excellently for one coal will not be suitable for another. For brown coal the angle is about 32°. The fuel should be of uniform size. Other suitable forms of grate are described.

**Pyrometry.**—The *Revue Industrielle de l'Est* publishes a paper by Bichat on the measurement of high temperatures. After drawing attention to the multiplicity of phenomena used in the construction of pyrometers, the author classes these apparatus into four distinct categories — (1) optical pyrometers, (2) calorimetric pyrometers, (3) thermo-electric pyrometers, and (4) dilatation pyrometers, and discusses the relative advantages of each.

C. v. Ernst † again discusses the Le Chatelier pyrometer. Referring to Wiborgh's adverse criticism, ‡ he points out that this pyrometer has already been introduced at numerous works, where it is constantly employed for the determination of very high temperatures, including iron and steel works, and its use has given general satisfaction. The author discusses the principle on which the pyrometer is based, and describes its construction.

\* *Zeitschrift des Vereines deutscher Ingenieure*, vol. xli. p. 403; seven illustrations.

† *Oesterreichische Zeitschrift für Berg- und Hüttenwesen*, vol. xlv. pp. 300–302; one illustration.

‡ *Journal of the Iron and Steel Institute*, 1896, No. II. pp. 294–296.







and giving in diagrams the productions of the several districts during the last twenty or thirty years. The statistics are also given in tabular form to show the production, number of workpeople, costs, accidents, &c.

**Coal from the Gard, France.**—M. Coignard \* gives the following results of assays of coal from the Gard :—

District.	Volatile Matter.	Ash.
	Per Cent.	Per Cent.
Bordezac . . . . .	18·50	16·30
Bessèges . . . . .	23·10	20·60
Bordezac . . . . .	21·10	14·10
Bordezac . . . . .	25·70	9·10
Bordezac . . . . .	21·20	11·50
Cessous . . . . .	7·60	

**The Rhenish Brown Coal Industry.**—C. Schott † observes that the Rhenish brown coal is chiefly employed in the manufacture of briquettes. The district in which workable seams of brown coal are found extends, in Tertiary rocks, for 15 miles in length, with an average breadth of rather over 3 miles. The average thickness of the over-burden is some 11 to 17 yards, and the average thickness of the seam some 98 feet. It is estimated that the available amount of brown coal in this field amounts to 3600 million tons. At the present time there are twenty active mining companies working this deposit, open workings being solely employed, the annual output being about 2,000,000 tons. The fine raw material is dried, heated, and compressed into briquettes under a pressure of about 200 atmospheres, the bitumen of the brown coal acting as a self-binding agent for the fuel. Given a proper grate, the raw brown coal will evaporate the same amount of water per square yard of boiler surface as ordinary bituminous coal, while it does not slag, and admits, too, of cheaper labour charges. At the present time the annual output of briquettes is some 600,000 tons, 70 presses being in use in 14 works.

**Coal in Prussia.**—Announcement is made by Von Rosenberg-Lipinsky ‡ of a new discovery of brown coal in the province of Posen, at Stopka, 12 miles north of Bromberg.

\* *Annales des Mines*, vol. xii. p. 90.

† *Stahl und Eisen*, vol. xvii. p. 464.

‡ *Zeitschrift für praktische Geologie*, 1897, pp. 247-250.

























Careful experiments made by the author show that a cubic metre of wood charged into the kiln contains :—

Kilogrammes.		Carbon.	Hydrogen.
		Kilogrammes.	Kilogrammes.
267·54	Cellulose . . . . .	138·05	17·39
186·49	Moisture . . . . .	...	20·72
1·67	Ash . . . . .	...	...
...	Difference . . . . .	...	1·48
455·70	Total . . . . .	138·05	39·59

The yield was found to be as follows :—

Kilogrammes.		Carbon.	Hydrogen.
		Kilogrammes.	Kilogrammes.
111·00	Charcoal . . . . .	91·30	4·60
3·40	Tar . . . . .	2·76	0·37
6·74	Acetic acid . . . . .	2·69	0·45
2·58	Methyl alcohol . . . . .	0·96	0·32
1695·93	Volatile gases . . . . .	40·34	...
304·69	Water . . . . .	...	33·85
...	Total . . . . .	138·05	39·59

On the other hand, a cubic metre of wood burnt in heaps gave :—

	Carbon. Kilogrammes.
Anhydrous charcoal . . . . .	74·53
Carbon lost . . . . .	63·52
Total . . . . .	138·05

This yield of 72·56 volumes per cent. in the kiln and 59·22 per cent. in open heaps shows an increased yield of charcoal of 22·53 per cent. in the case of carbonising in kilns.

#### IV.—COKE.

**Coke-Ovens.**—C. E. Bowron \* gives a cross section of a double bench of beehive ovens, with a flue for leading waste gases to boilers,

\* Report of the Bureau of Labour Statistics and Mines of the State of Tennessee, through the *Colliery Engineer*, vol. xviii. pp. 60-61.

as used at Tracy City, Tennessee, and elsewhere in the Southern United States.

It is stated \* that designs are being prepared for a coke-oven 200 feet long, with a moving bottom built up of tubes cooled by water circulation. The coking process is to be continuous.

Seventy-five ovens are being built near Raton, New Mexico. The waste gases are used for firing boilers, from which power is obtained to generate electricity for hauling and driving the machinery. Robinson washers are used.†

**Coke in the Southern United States.**—According to C. Haller,‡ most of the coke produced in the Southern United States is made in beehive ovens of about six tons capacity, and about a forty-eight hours burning for ordinary coke, or seventy-two hours for the best hard quality of coke. The latter quality, however, only forms about 10 per cent. of the total. The following are average assays of Alabama coke :—

Description.	I.	II.	III.
	Per Cent.	Per Cent.	Per Cent.
Moisture . . . . .	0·75	0·75	0·75
Volatile combustible matter . . . . .	0·75	0·75	0·75
Fixed carbon . . . . .	84·50	88·50	87·00
Ash . . . . .	14·00	10·00	11·50
Sulphur . . . . .	0·9 to 1·6	0·8 to 1·1	1·0 to 1·3

The ash contains :—

Description.	I.	II.	III.
	Per Cent.	Per Cent.	Per Cent.
Silica . . . . .	47·00	45·10	46·00
Ferric oxide . . . . .	12·46	12·32	12·00
Alumina . . . . .	33·62	31·60	32·00
Lime . . . . .	1·50	1·50	1·00
Magnesia . . . . .	1·69	trace	0·50
Sulphur . . . . .	0·75	0·50	0·60

Coke No. I. was made from coal just as it comes from the mine, while II. was from washed coal smalls, and III. from lump coal. In good coke, such as II., the volume of the cells amounts to from 45 to

\* *American Manufacturer*, vol. lx. p. 733.  
† *Engineering and Mining Journal*, vol. lxiii. p. 455.  
‡ *Stahl und Eisen*, vol. xvii. pp. 441–442.





















































ings. The daily cost of working an electric haulage plant at Johnson's mines at Scranton was stated to be as follows :—

	s.	d.
Station engineer . . . . .	7	0
Motor man . . . . .	7	0
Helper . . . . .	6	4
Repairs . . . . .	3	0
Depreciation . . . . .	7	7
Oil and waste . . . . .	0	10
Total . . . . .	31	9

The coal hauled per day amounted to 288 tons. The cost of haulage per ton was therefore 1½d. The cost by mule-power would be 3½d. per ton. In other instances of haulage cited by the author the cost per ton was as follows :—

Mine.	Electric Power.	Mule-Power.
	d.	d.
Peckville shaft . . . . .	1·31	3·29
Peckville adit . . . . .	0·85	1·17
Mount Pleasant mine . . . . .	0·63	1·47

There are numerous electric pumps at work in the anthracite region, and they are all giving satisfaction. One of the largest is that at the Maltby shaft of the Lehigh Valley Coal Company. This has a capacity of 600 gallons against a head of 350 feet. It is driven by a 50 horse-power electric motor. The cost of working a pump installed by the author in an anthracite mine per day of twenty-four hours was as follows :—

	s.	d.
Repairs . . . . .	1	10
Oil . . . . .	0	5
Electrician . . . . .	1	9
Total . . . . .	4	0

Compared with working a steam-pump, the saving is at least 6s. Electric rotary drills are largely used in the region with very advantageous results. At the mine of the Dolph Coal Company the cost of driving headings with the electric drill is 15s. per yard, the cost of driving by hand being 24s. In all the figures given, no charge has been made for steam used by the generating plant.

H. St. J. Durnford and R. Holiday \* describe the uses of electricity

\* *Transactions of the Federated Institution of Mining Engineers*, vol. xiii. pp. 232-241.





















































put?" "What arrangements admit of, and assist in, the utilisation of the coal smalls?" and "What progress can be observed in the use of small coal?" In addition to these there are the other commercial questions as to how far the increasing use of coal smalls affects the profit of a colliery; how far the variation in price between the different sizes of the same coal is to be explained; and what influence is exerted on this scale of prices by the increasing use of the small coal?

The author deals with these various questions. He shows that there are no available statistics showing what proportion of the total output consists of small and what proportion of large coal. This is doubtless due to the fact that the names given to the same sizes vary locally. It varies, of course, with the nature of the coal and its mode of occurrence. Dealing with an official publication about Austrian coals of the year 1878, the author shows that much information can be gained from this as to the point in question. He takes for the basis of his calculation the following classification—

For Coal.		For Brown Coal.	
Name.	Size.	Name.	Size.
	Inches.		Inches.
Large coal . . .	Over 3·54	Lump coal . . .	Over 3·94
Cubes (or Nuts I.) . .	3·54 to 1·58	Cubes (middle coal) . .	3·94 to 1·97
Nuts (or Nuts II.) . .	1·58 to 0·71	Coarse fines . . .	1·97 to 1·26
Smalls (or Nuts III.) . .	0·71 to 0·28	Middling fines (nuts) . .	1·26 to 0·55
Dust . . . . .	0·28 to 0·00	Fines I. . . . .	0·55 to 0·35
... . . . .	...	Fines II. . . . .	0·35 to 0·24
... . . . .	...	Dust . . . . .	Under 0·24

The nomenclature varies somewhat between the two kinds of coals, and the author gives that as customary in Austria, but he points out that not only the names vary locally, but the sizes also. The following are some examples given by the author to show the relative quantities of the different sizes occasionally noticed :—

Bituminous Coal.	Per Cent.
Large coal . . . . .	15
Cubes . . . . .	19
Nuts . . . . .	15
Smalls . . . . .	27
Dust . . . . .	34*

\* Probably 24, as the total is 110 per cent.



regular as possible, and in some methods of firing this regularity of size is a necessity. The difficulties in dealing with bituminous coal-smalls are very much less than in the case of brown coal smalls. The ideal use of small coal lies in the dust-firing methods. This not only yields a smokeless combustion and great economy of fuel, but it enables every particle of every kind of coal to be made available for combustion purposes.

The profit derived from a colliery depends on the first cost of the product raised, and on the best possible utilisation of the different minerals. With the first of these points the author does not deal, but he touches on the matters connected with the second. Competition with wood is not to be disregarded, this depending on the locality. With regard to the calorific value of the coal and brown coal mined in Austria, he observes that this varies from about 7000 down to 2500 calories. Schwackhöfer found as a maximum for Austrian coal 7441 calories, and as the minimum 4032. For brown coal the maximum was 5667, and the minimum 2096.

Of importance in connection with the price of a coal is its value for household use. It must be as free as possible from sulphur, contain little ash, and not be too dirty. It is not possible to say that the price for the different sizes of one and the same coal varies in accordance with any degrees of difference in their calorific value. Coal of as high a calorific power as possible is needed on shipboard, on account of the necessity for keeping down the weight as much as possible. Again, in boiler plants local conditions are all-important in determining the value of a coal. Similar considerations are general in all cases, especially where gas-firing is not employed.

**Briquettes.**—P. R. Björling \* describes and illustrates the machinery used for the manufacture of briquettes.

\* *The Colliery Guardian*, vol. lxxiv. pp. 556, 601, 647, 695, 738, 784.









































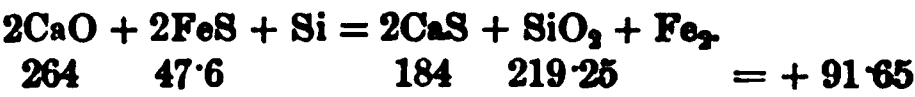






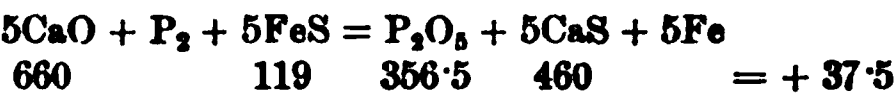


the furnace, and this metal expels the sulphur from combination with iron. The reduction of lime by carbon demands an enormous absorption of heat, but much less is required for its reduction by silicon, and the following exothermic equation may be considered :—



and some evidence based upon remarks by Snelus and Stead is given to support the possibility of this reaction. It is noted that the addition of lime to keep down silicon does not necessarily mean that silicon is not reduced.

In the basic process sulphur is chiefly removed during the after-blow, and the author ascribes much of the action to the phosphorus :—



This occurs during the after-blow when the lime is in solution.

The author concludes that, if his deductions are correct, it should be possible to desulphurise phosphoric metal after decarburisation, as actually happens in the basic Bessemer process, and it may become profitable to blow in an acid converter and finish in a basic furnace with the Saniter additions, the larger amount of phosphorus remaining in the acid-blown metal effecting an even greater elimination of sulphur than actually takes place at present.

**Pig Iron from the Ougrée Steelworks.**—These works are in the neighbourhood of Liège.\* The following are analyses of the ore smelted :—

No.	Loss.	SiO <sub>2</sub> .	Al <sub>2</sub> O <sub>3</sub> .	CaO.	MgO.	Mn <sub>2</sub> O <sub>3</sub> .	Fe <sub>2</sub> O <sub>3</sub> .	P.
	P. Cent.	P. Cent.	P. Cent.	P. Cent.	P. Cent.	P. Cent.	P. Cent.	P. Cent.
1.	18·50	6·30	8·90	8·00	0·40	0·32	56·60	0·72
2.	13·80	19·20	8·00	2·70	0·30	0·37	54·50	0·61
3.	6·92	15·00	10·00	2·50	1·30	0·10	61·96	0·56
4.	14·10	9·70	8·84	0·50	traces	27·57	38·42	0·12
5.	15·00	5·16	1·39	2·00	traces	22·93	49·13	0·21
6.	9·50	6·90	3·40	2·50	0·70	1·00	75·70	0·03
7.	6·78	7·10	1·82	0·30	traces	1·25	31·36	0·03
8.	1·34	11·30	2·71	2·00	1·50	12·77	67·38	0·05
9.	1·50	11·00	1·00	1·00	0·40	traces	82·74	0·06
10.	43·30	0·70	0·20	54·00	0·50	traces	0·30	0·01

In addition No. 3 contains 0·05 per cent. of sulphur, No. 8, 0·434 per cent., and No. 9, 1·15 per cent. The rest contain no sulphur, or only traces.  
(1) Oolitic iron ore from Luxemburg; (2) Oolitic ore from Belgium; (3) Iron glance from Namur; (4) Brown iron ore from Germany; (5) Brown iron ore from Greece; (6) and (7) Red hæmatites from Spain; (8) Calcined spathic ore, Germany; (9) Blue billy; (10) Limestone used as flux.

\* *Stahl und Eisen*, vol. xvii. pp. 816–817,



ganese, ore from Bayonne is added, its percentage composition being as follows :—

Silica . . . . .	6 to 8
Iron . . . . .	5 to 6
Calcium carbonate . . . . .	14 to 15
Alumina . . . . .	1 to 2
Phosphoric acid . . . . .	0·1 to 0·2
Manganese . . . . .	27 to 30

Ore from Huelva, with 14 to 18 per cent. of silica and 34 to 42 per cent. of manganese, is also used.

**Pig Iron from the Longwy Steelworks.**—The Longwy Steelworks are situated near Arlon, and not far from the Belgian-Luxemburg border.\* They possess altogether seven blast-furnaces, and smelt almost exclusively the oolitic ores of the adjacent district. Some Bilbao ore is used for a special brand of pig iron. The following are partial analyses of the local ores :—

	Hussigny.	Mont St. Martin.	Godbrange.	Herserange.	Moulaine.
	Per Cent.	Per Cent.	Per Cent.	Per Cent.	Per Cent.
Iron . . . . .	39·70	41·30	40·60	41·90	37·90
Manganese . . . . .	0·20	0·25	0·15	0·15	0·15
Silica . . . . .	11·95	17·83	12·59	10·95	13·60
Lime . . . . .	7·47	3·34	5·33	5·05	8·05
Alumina . . . . .	7·86	7·10	8·32	7·95	7·52
Sulphur . . . . .	0·20	n. d.	n. d.	0·30	n. d.
Phosphorus . . . . .	0·70	0·60	0·60	0·70	n. d.

n. d. = not determined.

The following are analyses of calciferous ores used in the charge for fluxing purposes :—

	Herserange.	Moulaine.	Hussigny.	Godbrange.	Saulnes.
	Per Cent.	Per Cent.	Per Cent.	Per Cent.	Per Cent.
Iron . . . . .	27·20	23·58	27·80	30·90	30·04
Manganese . . . . .	0·15	...	0·15	0·35	0·15
Silica . . . . .	11·85	9·90	9·36	10·60	11·25
Lime . . . . .	19·25	23·66	19·08	16·84	16·82
Alumina . . . . .	7·10	6·56	7·61	7·21	7·27
Sulphur . . . . .	0·25	n. d.	0·25	n. d.	n. d.
Phosphorus . . . . .	0·50	n. d.	0·50	n. d.	n. d.

n. d. = not determined.

\* *Stahl und Eisen*, vol. xvii. pp. 817–818.

















discovery appears to indicate the presence in the oolitic iron ore of Luxemburg of traces of zinc that have not yet been detected by analytical methods.

#### IV.—*FOUNDRY PRACTICE.*

**Recent Progress in the Foundry.**—R. Moldenke\* deals with recent progress in the foundry, due to the more rigorous application of scientific methods. Chemistry, for instance, has enabled scrap to be used more freely, and material is more generally bought on analysis. Less coke is used for melting iron, but the ratio cannot be much changed in the cupola for fear of oxidising the iron. Proposals for new cupolas multiply rapidly, showing that much interest is taken in the subject, but more is to be done with the regenerative gas-fired furnace. The improvements in fans, boilers, engines, cranes, and other appliances are briefly referred to, and also the transmission of power, moulding and cleaning machines. The nature of the iron used, and the methods for ensuring the proper quality of the mixtures are then dealt with at greater length, especially from the point of view of the chemist and the irregularity of the scrap, upon the sorting and grading of which so much depends.

Some correspondence on the application of science in the foundry from the above author and others has also appeared† in relation to the bursting of some rolls.

**The Behaviour of Silicon in Foundry Practice.**—Some data have been collected‡ of the behaviour of silicon in foundry practice, and the following table shows the percentage of this element in the pig and in the casting, crucible melting being employed :—

Pig iron . . .	0·90	1·70	0·55	2·69	0·56	0·68	0·73	2·49	0·30
Casting . . .	0·86	1·20	0·48	2·42	0·37	0·62	0·60	2·25	0·10

From these, and a number of similar results, the average reduction of silicon is calculated at 15·36 per cent. Varying opinions on the loss in cupola-melting are held. Thus, J. H. Geer states that in foundry practice it is usual to calculate a loss of 25 per cent. of the silicon from

\* Paper read before the Pittsburgh Foundrymen's Association, through the *American Manufacturer*, vol. lx. pp. 621-624.

† *American Manufacturer*, vol. lx. pp. 799 and 836.

‡ *Ibid.*, vol. lxi. p. 332.





















than that of the lost colonies of North America, for they would give to England the complete control of the iron trade. The discovery of crucible steel by Huntsman is dealt with. The manufacture of cement steel and of malleable castings is also referred to, and then the progress of the iron-founding industry is passed in review. This received an important impulse by the introduction of the method of remelting the pig iron, as at the beginning of the century, almost without exception, only direct castings were made. At the Carron works Jars saw five reverberatory furnaces used for remelting pig iron, and these were named *cupolas*, from the dome-like character of the roof. Shaft-furnaces, to which the name *cupola* was also generically applied subsequently when used for the same purpose, were not introduced until the eighties, their originator being J. Wilkinson. For decades afterwards they were called "Wilkinson furnaces."













# PRODUCTION OF STEEL.

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### I.—*THE CARBURISATION OF MALLEABLE IRON.*

**Crucible Steel-Making in America.**—In the United States but little attention has been paid to the manufacture of crucible steel, and most of the finer grades are imported. A large quantity of that now made is prepared according to the formulæ of thirty years ago, but with inferior material. When the manufacture was first introduced, imported Swedish iron and leaf spring scrap were used, but local scrap is now used; and as this spring steel is made from Bessemer steel, containing both sulphur and phosphorus, instead of from crucible steel of fair quality, the grade has deteriorated. Greater use is now made of chemical analysis, and so many advances are being made. Carburising imported iron by cementation was the first to disappear, although some works use the process for domestic iron. Charcoal iron made in the country was first substituted for imported iron, and then its place was taken by puddled coke iron or muck-bar, and a correspondingly inferior article was made. Much attention is given to the introduction of alloys into the crucible, and the process is generally attracting greater attention.\*

A. C. Cunningham† states that ordinary steel castings are often stamped as cast steel, and then proceeds to discuss the requirements of the former.

\* *Iron Age*, vol. lx. No. 5, pp. 5-6.

† *Railroad Gazette*, vol. xxix. p. 449.





















the respective carbon percentages 1·54, 0·88, and 1·46, but these were for blows of from eight to fourteen minutes. The length of blow finally adopted was five minutes, as in the first case quoted.

H. G. Graves \* briefly reviews some of the recent economies in iron and steel manufacture. Reference is made to Bonehill's direct puddling process, the Bertrand-Thiel open-hearth process, the Walrand process, the recovery of by-products and the utilisation of blast-furnace and basic slag.

J. Hartshorne † shows that there is an economy in time due to the use of the Bertrand-Thiel process, and also discusses the loss of iron, which is least when smaller amounts of scrap are used. It is not fair to charge to the loss the iron introduced as ore.

**Open-Hearths at the Duisburg Steelworks.**—According to C. Caspersson,‡ there are two open-hearths at this works, and these are provided with cylindrical gas-producers. They are lined with dolomite, the bottoms being stamped in the usual way. At the back are four layers of dolomite bricks. Outside these, and between them and the outer thin wall of acid bricks next the plate, is stamped in the ordinary dolomite material. Magnesite is used between the acid roof and the dolomite lining. Similar details are given as to the other parts of the furnace. The dolomite bricks are stamped out of a tar-dolomite mass in iron moulds, and are burnt in a kiln two yards in length, in which are placed four rows of fifty bricks each. The kiln is fired with coal. Six hours after firing the tar in the bricks begins to burn. The coal firing then ceases, and the tar is allowed to burn itself out, which it does in the course of three hours. The bricks are then allowed to cool down slowly. The dolomite is calcined with the aid of coke in a cupola lined at the bottom with acid bricks, and above with dolomite. The method of starting a newly repaired furnace is described, and also the use of the furnace generally. Körting injectors are used in driving the producers. From pig iron containing 0·2 to 1·0 per cent. of phosphorus, iron of excellent quality is stated to be made. The tapping is done with conical moulds connected with one another, with the wide end at the bottom. Ingots of very good quality result. The roof of a furnace usually lasts seven or eight weeks, and the bottom three-and-a-half to four months. The regenerator chambers

\* *The Mineral Industry*, vol. v. pp. 377-381.

† *American Manufacturer*, vol. lx. pp. 368-369.

‡ *Jernkontorets Annaler*, vol. li. pp. 319-327.













Discussing the use of mixers, the author refers to the separation of sulphur in these. At each plant there are usually two each of 100 to 150 tons capacity. The charging is effected either by means of an engine and an inclined plane, or else indirectly by means of a hoist of some sort. In tabular form is given the results of a large number of partial analyses of samples from such a mixer, as well as of the iron charged into it, showing clearly the averaging character of the mixer when charged with iron of very varying composition. The action of the manganese in eliminating sulphur is clearly indicated in these. Another very interesting point shown is the extent to which sulphur is eliminated in the ladle used to convey the iron from the blast-furnace to the mixer. About one-half the total quantity was thus eliminated. The following are a few of the analyses showing the elimination :—

At the Blast-Furnace.		When Charged into the Mixer.	
Manganese.	Sulphur.	Manganese.	Sulphur.
Per Cent.	Per Cent.	Per Cent.	Per Cent.
1·03	0·19	0·85	0·10
1·13	0·20	0·86	0·10
1·03	0·25	0·70	0·14
1·13	0·22	0·80	0·07
1·31	0·20	1·17	0·08
0·75	0·19	0·56	0·14
0·75	0·22	0·51	0·16
0·99	0·24	0·75	0·14
1·60	0·18	0·84	0·06
1·55	0·15	0·99	0·08

The following are similar partial analyses of this metal as poured into the converter after passing through the mixer :—

Manganese.	Sulphur.
Per Cent.	Per Cent.
0·90 . . . . .	0·04
0·84 . . . . .	0·04
0·75 . . . . .	0·07
0·80 . . . . .	0·06
0·71 . . . . .	0·06
0·67 . . . . .	0·09
0·61 . . . . .	0·10
0·71 . . . . .	0·08
0·71 . . . . .	0·07
0·84 . . . . .	0·06
0·75 . . . . .	0·09
0·80 . . . . .	0·07



























He observes that the results just referred to show the following as being the order of relative merit of the different systems of firing :—

1. Water-spray with coke.
2. Coke fire.
3. Coal fire with bottom blast.
4. "Coke" fire, but using coal.
5. Water-spray with coal.
6. Coal fire with side blast.

The latter represents the ordinary smith's fire. The action of the finely divided water is thought to be mechanical. It forces its way into the interior of the fuel, is vaporised, and splits the fuel up into finer particles, thereby facilitating their combustion.







































the punching and shearing, and during the punching out of the blank. The effect of time, size, and the factors which bear on the difference in results are then discussed, after which attention is turned to the deterioration caused by punching and to the methods of obviating these effects.

**The Results of Mechanical Tests.**—O. Knaudt \* discusses the degree of accuracy that is attainable in the testing of iron and steel. He instances a case in which samples of the same materials were sent to the testing laboratory at the Technical School at Munich, the Charlottenburg Testing Institute, and the Zürich Polytechnic. The samples had been previously tested at the works from which they were delivered. The testing laboratories above referred to are typical, and the appliances in use the best obtainable. Yet the results were not identical, as the following tables show :—

*Tensile Strength (Tons per Square Inch).*

	I.	II.	III.	IV.
Original works . . . . .	23·1	23·9	22·4	21·9
Charlottenburg . . . . .	22·2	23·2	22·3	21·6
Zürich . . . . .	23·2	23·9	22·9	22·4
Munich . . . . .	22·8	23·4	22·8	22·0

*Elongation per Cent.*

	I.	II.	III.	IV.
Original works . . . . .	27·4	31·2	31·0	31·0
Charlottenburg . . . . .	30·0	30·5	30·4	29·5
Zürich . . . . .	29·9	32·6	29·9	28·4
Munich . . . . .	27·2	28·2	32·4	29·4

Samples I. were from the works of Messrs. Schulz Knaudt ; samples II. from Messrs. Krupp ; samples III. from Hörde ; and samples IV. from Messrs. Thyssen & Co. The metal from which the samples were taken consisted of an ingot iron firebox plate. It will be seen that, as regards tensile strength, there was in some cases a considerable difference, while in the elongation tests this difference was marked ; and the author observes that from the results of these tests it may be con-

\* *Stahl und Eisen*, vol. xvii. pp. 619-622, with one table.





















































furnace hearth, where it must have been molten for over a year, and then have cooled very slowly. It is light, silvery and crystalline, with a rectangular cleavage. At the same time it is very malleable, and is scarcely touched by the drill. After hardening, a few strokes of the hammer made it malleable again, and the original mass could be split up into cubes, which flattened out to thin plates under a hammer. Analysis showed :—

Mn.	Si.	S.	P.	C.
0·0362	0·0262	0·0106	0·8285	0·1035

The second sample was a piece of wire which had supported an incandescent mantle, and where it was exposed to the flame it had become very brittle. Analysis showed 0·0362 per cent. of carbon in the unaltered portion and 0·0978 in the altered part.

**The Condition of Phosphorus in Steel.**—E. D. Campbell and S. C. Babcock\* describe some experiments on the influence of heat treatment and carbon upon the solubility of phosphorus in steel. Samples of the metal were raised to between 900° C. and 1000° C., and allowed to cool slowly, or were quenched in water at 4° or 5° C. from various temperatures. The amount of phosphorus soluble in an acid mercuric chloride solution was then determined by methods which are fully described. The results are given as follows :—

Chemical Composition.			Heat Treatment.	Quenching Temperature.	Per Cent. of Phosphorus Soluble in Acid HgCl <sub>2</sub> .	Per Cent. of Total Phosphorus Soluble in Acid HgCl <sub>2</sub> .
C.	P.	Mn.		°C.		
0·10	0·119	0·484	Annealed	...	0·099	83·2
0·10	0·119	0·484	...	719	0·081	68·08
0·10	0·119	0·484	...	825	0·079	66·4
0·10	0·119	0·484	...	928	0·080	67·2
0·10	0·119	0·484	...	1,028	0·086	72·2
0·37	0·160	0·820	Annealed	...	0·137	85·6
0·37	0·160	0·820	...	728	0·110	68·8
0·37	0·160	0·820	...	827	0·066	41·2
0·37	0·160	0·820	...	923	0·048	30·0
0·37	0·160	0·820	...	1,027	0·049	30·6
1·22	0·098	0·780	Annealed	...	0·098	100·0
1·22	0·098	0·780	...	719	0·087	89·8
1·22	0·098	0·780	...	750	0·051	52·0
1·22	0·098	0·780	...	825	0·018	18·3
1·22	0·098	0·789	...	923	0·015	15·3
1·22	0·098	0·780	...	1,023	0·016	16·2

\* *Journal of the American Chemical Society*, vol. xix. pp. 786-790.



amount of pigment in the paint. Slow-drying paints put on in several layers are to be preferred.

Iron articles which have become greatly attacked by rust can be very readily cleaned by plunging them into a fairly concentrated solution of stannic chloride. They should be left in for, as a rule, about twelve to twenty-four hours. The solution should not contain an excess of acid.\*

**Action of Iron on Solutions of Metallic Nitrates.**—Jean B. Senderens† has studied the action of different kinds of iron (wrought iron, piano wire, &c.) on dilute solutions of silver salts, and finds that unworked iron is far more active than worked iron, precipitating the silver readily from dilute solutions of the nitrate. This he attributes to a difference in the physical condition in the different samples of iron.

\* *Oesterreichische Zeitschrift für Berg- und Hüttenwesen*, vol. xlv. p. 580.

† *Bulletin de la Société Chimique*, vol. xv. pp. 691–700. See p. 76 of this volume.













































# STATISTICS.

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### I.—UNITED KINGDOM.

**Mineral Statistics.**—According to the official report of Her Majesty's Inspector of Mines,\* the production of coal in the United Kingdom in 1896 amounted to 195,361,260 tons. The production during the previous year was 189,661,362 tons. The total quantity of iron ore raised in 1896 was 13,700,764 tons, of which 7,856,586 tons was obtained from mines under the Coal Mines Regulation Act, 2,237,600 tons from mines under the Metalliferous Mines Act, and 3,606,578 tons from open works.

The production of pig iron in 1896 is officially stated to have been as follows :—

	Tons.
Hæmatite . . . . .	3,647,972
Ordinary and basic . . . . .	4,814,976
Spiegeleisen, ferro-manganese, &c. . . . .	196,733
Total . . . . .	8,659,681

The estimate of the British Iron Trade Association was 8,563,209 tons.

\* “Mineral Statistics of the United Kingdom.” London, 1897.



II.—AUSTRALASIA.

**Mineral Statistics of New South Wales.**—The official statistics of the Colony of New South Wales \* show an increase of 170,927 tons of coal in 1896, as compared with the previous year. The average price per ton is given as 5s. 9·06d., being lower than ever it has been before. The export trade is increasing. At the end of 1896 there were ninety-six coal-mines and five shale-mines under inspection, a decrease of three and two respectively as compared with the previous year. The figures for 1896 are as follows, those for 1895 being added for comparison :—

	1896.	1895.
Exports to intercolonial ports, tons . . . . .	1,371,796	1,196,504
Exports to foreign ports, tons . . . . .	1,103,111	969,726
Home consumption, tons . . . . .	1,434,608	1,572,359
Total output, tons . . . . .	3,909,517	3,738,589
Men employed in coal and shale mines . . . . .	9,460	9,022
Accidents, fatal . . . . .	24	10
„ non-fatal . . . . .	62	47
Coke made . . . . .	26,351	27,630
Shale produced . . . . .	31,839	59,426

Negotiations are still proceeding with a view of establishing iron ore smelting works in the colony of New South Wales. Some ore is raised for use as flux, and some new deposits have been found. Finished iron made from scrap has been manufactured to the amount of 4721 tons in 1896. No manganese mining is being carried on at present.†

**Mineral Statistics of Victoria.**—According to the official returns,‡ the quantity of coal raised in 1896 amounted to 226,562 tons. Details are given in the report of numerous borings put down in search of coal. The report also contains a memoir by J. Sterling on systems of mining coal in Victoria.

**Mineral Statistics of Western Australia.**—According to the official returns,§ the quantity of coal raised during 1896 was 9801 tons. The mines are still in early stages of development.

\* *Annual Report of the Department of Mines*, 1896, pp. 40–45, 74–76, 86–95.  
† *Ibid.*, p. 50.  
‡ *Annual Report of the Secretary for Mines*. Melbourne, 1897, p. 13.  
§ *Report of the Department of Mines*, Perth, 1897, p. 21.



trade of the Austro-Hungarian Customs Union has been issued for the year 1896. The mineral imports and exports were as follows :—

	Imports.	Exports.
	Tons.	Metric Tons.
Brown coal . . . . .	19,981	7,562,720
Coal . . . . .	5,175,321	658,367
Coke . . . . .	491,028	116,607
Manganese ores . . . . .	7,371	701
Iron ores . . . . .	107,017	254,389

The increase in the exports of iron ore is noteworthy. Compared with the previous year the increase is 53 per cent. The ore is all absorbed by Germany.

**Accidents in Mines and Works.**—In the year 1895 \* there were in Austria 559 mining and 83 smelting works undertakings in active operation. In mining there were employed 117,177 workpeople, and in the smelting works 8312. Of the total number 125,489, 113,172 were men, 6815 women, the remainder being girls and youths, with the exception of 7 children.

In coal-mining 54,563 were employed, in brown coal mining 45,182, in iron ore mining 4502, and in ironworks 6297, all through totals showing increases over the similar figures for the year 1894. Of the total number, 125,489, no less than 55,019 were employed in Bohemia, 23,314 in Silesia, 14,261 in Styria, and 9184 in Moravia. Next to these comes Galicia with 4049 and Carinthia with 3668.

In 1895 there were 909 accidents in Austrian mines. These included 6 fatal accidents to women, and 203 to men and young people, while the severe accidents numbered 8 among the women and 692 among the remainder. In smelting works there were 4 fatal and 16 severe accidents. These accidents included :—

Mineral.	Accidents.			
	Fatal.		Severe.	
	1895.	1894.	1895.	1894.
Coal . . . . .	107	276	259	226
Brown coal . . . . .	80	93	364	314
Iron ore . . . . .	8	3	18	33

\* *Oesterröichische Zeitschrift für Berg- und Hüttenwesen*, vol. xlv. pp. 304–306.



Number of mines . . . . .	44
Number of shafts in operation . . . . .	289
Number of shafts being sunk . . . . .	32
Number of shafts abandoned . . . . .	413
Production, in tons . . . . .	7,210

**Mineral Statistics of Bosnia and Herzegovina.**—According to official statistics, the mineral production of Bosnia and Herzegovina in 1896 included :—

	Metric Tons.	Value.
		£
Iron ore . . . . .	23,213	4,961
Chrome ore . . . . .	442	1,356
Manganese ore . . . . .	6,821	11,254
Iron pyrites. . . . .	2,000	1,000
Brown coal . . . . .	222,724	46,957

The number of persons employed in the mines and smelting works included :—

Coal-mining . . . . .	838
Iron-mining . . . . .	163
Ironworks . . . . .	501

The improvements introduced during the year include the erection of a second blast-furnace for 30 tons of pig iron daily, with two new hot-blast stoves and a compound steam-engine at the Veres Ironworks, as well as the construction of a branch railway, 15 miles in length, from these works to the Podlugovi station of the Bosnian State Railway. A coal-washing plant, with a capacity of 500 tons a day, has been erected at the Zenica Coke Works. At the Kreka Colliery new pumps have been put in, and electrical transmission for working a Rateau fan has been installed.

The output of pig iron in Bosnia and Herzegovina in 1896 amounted to 10,120 tons, an increase of 7551 tons as compared with the output in 1895. Of castings 1039 tons was made, and of open-hearth ingots 3265 tons. In 1895 no open-hearth ingots were made. Of rolled iron the output in 1896 amounted to 5418 tons.\*

\* *Stahl und Eisen*, vol. xvii. pp. 518-519; *Oesterreichische Zeitschrift für Berg- und Hüttenwesen*, vol. xlv. pp. 223-224.





quality was discovered in Cape Breton during the year, which is well situated for mining and exporting at a moderate cost.

The coal industry is an old one, the records showing that 1668 tons were mined as long ago as 1786, and yearly statements of production have been made from that date up to the present time, 112 years. Nowhere else in America can such statistics be found. The production grew gradually, but very slowly ; up to 1850, 180,084 tons were reported. By 1860 the output had grown to 322,593 tons ; in 1870, to 568,270 tons ; in 1880, to 954,659 tons ; in 1890, to 1,786,111 tons ; and in 1896 it was 2,047,133 tons.

According to the reports of the Division of Mineral Statistics and Mines of Canada, there were produced in 1896 the following amounts :—

	Tons.
Coal . . . . .	3,395,807
Coke . . . . .	45,194
Iron ore . . . . .	80,019
Manganese ore . . . . .	11

**Metallurgical Education in Canada.**—At the recent meeting of the Society for the Promotion of Engineering Education held at Toronto, M. E. Cooley \* urged the importance of engineers having some knowledge of metallurgy. The materials most largely used by engineers are cast iron, steel, and bronze, and it is becoming the practice to specify for cast metals with as much care as for wrought metals. And with skilful workmen and an educated foundryman, it is not a difficult matter to obtain castings that will fulfil the requirements of specifications. To accomplish this, the engineering student ought to have a certain amount of training in metallurgy.

## VI.—CUBA.

**Iron Ore.**—Broadly speaking, about 80 per cent. of all the iron ore now imported into the United States comes from Cuba. The amount shipped from Cuba to the United States in 1896 was 409,883 tons, whilst the total supplies of foreign ore brought into the country amounted to 543,241 tons.†

\* *Railroad Gazette*, vol. xxix. p. 597.

† *Age of Steel*, vol. lxxxii. No. 9, p. 20.

VII.—*FRANCE.*

**Iron Trade Statistics.**—The Comité des Forges de France \* has published statistics of the French production of iron during the first half of 1897. The out-turn is as follows :—

	Tons.
Pig iron . . . . .	1,223,638
Wrought iron . . . . .	405,696
Steel . . . . .	630,143

The production of steel included 404,923 tons of Bessemer metal, a large portion of which was obtained by the dephosphorisation of phosphoric pig iron by the basic Bessemer process in the departments of Meurthe-et-Moselle, Ardennes, and Saone-et-Loire.

VIII.—*GERMANY.*

**Imports and Exports.**—The Society of German Iron and Steel Masters has issued complete statistics † of the German iron trade exports and imports for 1896. The leading items are as follows :—

	Imports.	Exports.
	Tons.	Tons.
Iron ore . . . . .	2,586,705	2,642,294
Pig iron . . . . .	322,501	140,449
Manufactured iron and steel . . . . .	82,514	1,273,003

Compared with the statistics of other countries, the imports and exports of pig iron in 1896 bore the following percentage proportion to the production :—

	Imports.	Exports.
Germany . . . . .	5·3	3·8
Austria-Hungary . . . . .	13·5	1·1
France . . . . .	4·8	10·2
Great Britain . . . . .	0·2	17·1
Belgium . . . . .	42·6	3·2

In the case of manufactured iron and steel the percentages were as follows :—

\* *Bulletin*, No. 1206.† *Ibid.*, No. 17.

	Imports.	Exports.
Germany . . . . .	1·4	21·3
Austria-Hungary . . . . .	6·2	3·7
France . . . . .	1·5	5·6
Great Britain . . . . .	5·9	36·7
Belgium . . . . .	2·3	47·7

The production of pig iron in the various countries in 1896 is stated to have been as follows :—

	Pig Iron in Thousands of Tons.	Number of Inhabitants in Millions.	Production per Head, Lbs.
Germany . . . . .	6,342	52·2	265
Great Britain . . . . .	8,700	39·5	490
France . . . . .	2,334	38·5	133
Austria-Hungary . . . . .	1,100	45·0	53
Belgium . . . . .	933	6·5	315
Sweden . . . . .	475	5·0	210
Italy . . . . .	10	31·0	6
Russia . . . . .	1,390	130·0	23
United States . . . . .	8,623	71·0	270

**Production of Basic Steel.**—The Society of German Iron and Steel Masters has issued statistics \* of the production of basic steel in the German Empire in 1896. The figures are as follows :—

	Tons.
In the converter . . . . .	3,004,615
In the open-hearth . . . . .	1,292,832
Total . . . . .	4,297,447

The corresponding totals for the years 1894 and 1895 were respectively 3,241,272 and 3,539,203 tons.

**Brown Coal Production of Germany.**—According to Kaestner,† the output of brown coal has increased very rapidly in Germany in recent years, and he gives the following details :—

Year.	Workpeople Employed.	Output.	Value.
		Metric Tons.	£
1880	25,358	12,144,500	1,835,500
1885	28,186	15,355,100	2,019,000
1890	33,161	19,053,000	2,488,500
1895	37,476	24,788,000	2,900,500

\* *Bulletin*, No. 11.

† *Zeitschrift des Vereines deutscher Ingenieure*, vol. xli. p. 404.



there were produced in Upper Silesia the following quantities of the substances named in 1896 and in the two preceding years:—

	1896.	1895.	1894.
	Metric Tons.	Metric Tons.	Metric Tons.
Coal . . . . .	19,586,152	18,063,906	17,195,918
Brown iron ore . . . . .	460,775	467,161	551,720
Clay iron ore . . . . .	1,048	613	2,472
Iron ores from lead and zinc mines . . . . .	7,556	7,920	5,808
Coke pig iron . . . . .	615,419	531,677	513,803
Charcoal pig iron . . . . .	609	562	719
Castings . . . . .	53,123	41,968	37,282
Semi-manufactures, weld iron . . . . .	16,917	9,644	9,565
Semi-manufactures, ingot metal . . . . .	97,434	71,641	58,181
Manufactures, iron and steel . . . . .	543,785	520,526	418,838
Coke . . . . .	1,188,490	1,113,706	1,062,179
Tar and ammonia water from coke-works . . . . .	80,232	75,847	59,408

The number of workpeople employed at the collieries in Upper Silesia in 1896 amounted to 56,032, the highest total yet reached. The output amounted to 349·6 tons per miner. The average value of the metric ton of coal was 5s. 2½d. Of the total quantity of coal raised, 21·0 per cent. was classed as lump, 26·1 as smalls, and 14 as dust and fine coal. Of the total quantity of coal consumed in Berlin in 1896, 57·12 per cent. was derived from Upper Silesia, and 20·08 per cent. from the United Kingdom, as compared respectively with 61·93 per cent. and 16·15 per cent. in the previous year.

The active iron ore mines numbered 47 in 1896, as compared with 45 in 1895. Coke was made at 14 works; 13 different types of coke-oven were in use. The coke-works produced 1,007,987 tons of lump coke, 89,462 tons of smalls, 91,041 tons of “cinder,” and 80,232 tons of by-products.

Pig iron was made at 11 works, possessing 37 blast-furnaces, of which 28 were in blast for 1362 weeks. The consumption of fuel per ton of iron made is steadily diminishing, and amounted to 1·292 ton in 1896. The following table shows the kind of iron made:—

	1896.	1895.	1894.
	Metric Tons.	Metric Tons.	Metric Tons.
Forge pig iron . . . . .	349,620	326,067	332,451
Foundry pig iron . . . . .	52,665	37,905	42,110
Basic pig iron . . . . .	182,032	132,882	106,558
Bessemer pig iron . . . . .	31,092	33,863	32,207

Of the 53,123 tons of castings mentioned in the general summary as having been made in 1896, 13,817 tons consisted of pipes, and 3408

tons were steel castings from cupolas and open-hearths. The usual details relating to the steelworks are also given. During 1896 the reconstruction of the Gleiwitz blast-furnace plant was completed, and the furnaces were started.<sup>1</sup>

**The Iron Industry of Siegen.**—The following are some details given in connection with the iron industry of Siegen, Germany : \*—

*Production of Iron Ore.*

	1895.	1896.
Active iron ore mines . . . . .	155	178
Workpeople employed . . . . .	12,674	13,280
Iron ore raised, metric tons . . . . .	1,531,991	1,765,509
Total value . . . . .	£550,539	£772,597
Value per ton, shillings . . . . .	7·18	8·75

*Production of Pig Iron.*

	1895.	1896.
Pig iron made, metric tons . . . . .	455,158	598,291
Value of pig iron made . . . . .	£1,019,525	£1,539,103
Workpeople employed . . . . .	1,751	2,105

The blast-furnaces in blast remained in 1896 as in 1895.

The total production of all the mills (forges and puddling furnaces) generally was as follows :—

	1895.	1896.
Total production, metric tons . . . . .	189,484	234,673
Value of product . . . . .	£973,615	£1,345,120
Workpeople employed . . . . .	2,804	3,317

In the iron foundries in this district the out-turn was as follows :—

	1895.	1896.
Total production, metric tons . . . . .	30,227	35,994
Value of product . . . . .	£215,846	£279,322
Workpeople employed . . . . .	958	1,075

\* *Stahl und Eisen*, vol. xvii. pp. 555-556.

During the year a syndicating arrangement was come to between the Siegen and the Rhenish-Westphalian Works as to the sale of their outputs.

**Mineral Statistics of Bavaria**—The statistics of mineral production in Bavaria in 1896 have been issued. They comprise the following :—

	Number of Mines.	Metric Tons.	Number of Miners.
Coal . . . . .	19	900,080	5,427
Lignite . . . . .	8	35,934	264
Iron ore . . . . .	44	161,279	719
Manganese ore . . . . .	1	70	2
Iron pyrites . . . . .	2	1,997	45

The metallurgical production included : \*—

	Metric Tons.
Pig iron . . . . .	79,621
Castings . . . . .	71,006
Bar iron . . . . .	53,573
Iron wire . . . . .	243
Steel . . . . .	101,954

**Production of Coal in Prussia**.—The following details are given by Kaestner † as to the production of bituminous coal in Prussia :—

Year.	Number of Collieries.	Workpeople Employed.	Output.	Value.
			Metric Tons.	£
1880	392	155,006	42,172,944	10,530,853
1885	375	193,188	52,879,004	13,144,100
1890	342	233,754	64,373,816	23,976,192
1895	260	271,604	72,621,509	23,977,721

According to the official statistics, the production of coal in Prussia during the first half of 1897 amounted to 40,017,473 tons ; 268 collieries were in operation, and 296,412 workmen employed. The production of brown coal during the same period was 11,226,562 tons from 369 mines, 31,709 workmen being employed.

\* *Oesterreichische Zeitschrift für Berg- und Hüttenwesen*, vol. xlv. pp. 408–409.

† *Zeitschrift des Vereines deutscher Ingenieure*, vol. xli. p. 404.





and industry in the second half of the year were such as to greatly restrict the consumption of coal. The production of coal in India in 1896 amounted to 3,848,013 tons, being in the ratio of about  $7\frac{3}{4}$  tons locally produced to one ton imported. This is much the largest ratio as yet known, and it will perhaps hardly be maintained for some years to come,; for although the production of Indian coal increases while the importation of coal is gradually dwindling, last year was quite exceptional in its conditions.\*

Valuable details of the progress of the various collieries in India are given in Colonel Gracey's last report † on the administration of railways in India.

XI.—ITALY.

**Iron Trade Statistics.**—The production of steel in Italy in 1896 amounted to 55,000 tons. In 1889 the out-turn was as much as 157,889 tons. Since that date it has gradually decreased.

There are only two steelworks in Italy, the Terni Steelworks, which possesses two large acid Bessemer converters and five open-hearth furnaces, and the Savona Steelworks, with nine Batho furnaces, one of which is acid and the others basic.‡

According to official returns § the mineral production of Italy in 1896 included :—

	Metric Tons.
Brown coal . . . . .	276,197
Iron ore . . . . .	203,966
Manganese ore . . . . .	33,705
Manganiferous iron ore . . . . .	10,000
Petroleum . . . . .	2,524

XII.—JAPAN.

**Iron Trade Imports.**—In Japanese consular reports which have just been issued it is stated || that the whole value of metals imported into Nagasaki in 1896 amounted to £225,629 as compared with only £49,712 in 1895. The value of the locomotives, machinery, and boilers

\* *Indian Engineering*, vol. xxii. p. 229.  
† *Colliery Guardian*, vol. lxxiv. p. 332.  
‡ *Mining Journal*, vol. lxxvii. p. 843.  
§ *Rivista del Servizio Minerario nel* 1896.  
|| *Birmingham Daily Mail*, October 15, 1897.



workshops made progress during the year. The following quantities of materials were imported in the years named :—

	1896.	1895.
	Value, £.	Value, £.
Iron wares . . . . .	341,677	162,113
Bar iron . . . . .	28,316	9,977
Plates . . . . .	11,177*	8,220*
Sheets . . . . .	11,177*	8,220*
Corrugated sheets . . . . .	117,395	56,897
Pipes . . . . .	6,714	3,595
Fencing wire . . . . .	62,271	32,469
Machines . . . . .	367,870	52,888

XV.—RUSSIA.

**Mineral Statistics.**—The last report of the Government Department of Mines gives the following statistics of the mineral production of Russia in 1895 :—

	Tons.
Coal . . . . .	9,009,000
Naphtha . . . . .	6,978,000
Pig iron . . . . .	1,427,000
Wrought iron . . . . .	415,400
Steel . . . . .	557,100

The number of workmen employed in the mines and works amounted in 1895 to 460,000, of which number 89,000 worked at gold mines, 7500 in the naphtha industry, and 22,000 at the salt-mines. In the year 1896 the Russian ironworks produced 98,414,000 poods of pig iron, 30,661,000 poods of wrought iron, and 42,596,000 poods of steel.

F. J. Guyon † discusses the industrial awakening of the Russian Empire, and briefly describes the recent advance and present state of coal and iron mining and manufacture in that country.

**Coal.**—M. Verstraete, of the French Consular Service, has published a memoir on the present condition of Russian trade. Coal, which has been hitherto worked chiefly in the Donetz basin and in Poland, has been discovered in enormous quantities in Siberia. Moreover, thick beds of excellent coal occur in the Ural in association with rich iron ores. Russia in 1880 raised 3,296,000 tons of coal and imported

\* As in original. † *Engineering Magazine*, vol. xiv. pp. 64–69.



considerable amount of flux, chiefly limestone. There are no data regarding the cost of limestone at the quarries. After discussing the economical position of the chief works and the railway freights for the raw materials, it is concluded that the cost of pig iron per pood at the works should be—

	Krivoi Rog Ore only.	Krivoi Rog Ore, together with One- third of Poor Ore.
	Copecks.	Copecks.
Ore . . . . .	9·60	17·29
Flux . . . . .	3·00	2·00
Coke . . . . .	23·37	11·82
Coal . . . . .	0·60	0·25
Labour and standing charges .	8·00	8·00
Totals . . . . .	44·57	39·37

or from 40 to 45 and from 35 to 40 copecks per pood. Foundry pig-iron will be 2 to 3 copecks dearer. It is also estimated that the cost of manufacturing Bessemer rails will be 90 to 95 for the works using Krivoi Rog ore only, and 80 to 85 for those smelting mixed ores; of open-hearth rails, the same; of puddled iron, 1 rouble 35 copecks and 1 rouble 20 copecks; of sheet iron, 1 rouble 40 copecks and 1 rouble 25 copecks.

A comparison is then made between the above estimated cost of production and of the market prices. Thus the market price of pig iron is given at 60 to 65 copecks per pood, a difference of nearly 50 per cent. above the cost of production. The dividends paid by the works in 1895-96 are given: the Hughes Works, 100 per cent.; the Briansk Works, 30 per cent.; the Dneiprovsk Works, 40 per cent.; and the lately erected Drougekoffsky Works, 6 per cent.

**The Iron Industry.**—A. Radzig\* observes that at the end of the past century the production of pig iron in Russia considerably exceeded that of Great Britain. The reason why the latter has since made such relatively enormous progress lies in the fact that even in the last century the use of coal, instead of charcoal, was introduced in Great Britain, while up to recent times in Russia this had not been done to any large extent. In the Urals the iron industry dates from the beginning of the seventeenth century. The first ironworks there were erected by the State. In Central Russia the iron industry developed very slowly in a

\* *Stahl und Eisen*, vol. xvii. pp. 538-543.



duty on pig iron was five copecks the pood, and during this period the production increased 20 per cent. From 1887 to 1891 the duty was as much as twenty-five copecks the pood, and the increase in production during this term was as much as 65 per cent.

Details are given as to the iron trade imports into Russia for the years 1857-76, and then in another table is shown the number of blast-furnaces and their production in the Urals, Poland, and South Russia for each of the years 1882-93 :—

Year.	Urals.		Poland.		South Russia.	
	Blast-Furnaces.	Average Annual Capacity.	Blast-Furnaces.	Average Annual Capacity.	Blast-Furnaces.	Average Annual Capacity.
		Tons.		Tons.		Tons.
1882	103	2936	31	1383	3	6,424*
1890	107	4242	30	4242	9	24,184
1893	113	4459	29	5690	13	25,035

The author points out that in 1894 the average annual out-turn per blast-furnace was in the United Kingdom 23,210 tons, about the same as that in South Russia ; in Belgium the average yield was 25,880 tons, and in the United States 49,140 tons per furnace.

Details are next given as to the number of workpeople employed, and the number of water-wheels, turbines, and steam-engines used for power. Details as to the production of iron and steel up to 1893 are also shown, together with others relating to the consumption.

XVI.—SOUTH AFRICAN REPUBLIC.

**Coal Production.**—The report of the State Mining Engineer † gives the total tonnage of coal shipped from all the Transvaal mines in 1896 at 1,471,189 tons, against 1,152,206 tons in 1895, showing an increase of 318,983 tons. The total reported sold in 1896 was 1,437,297 tons, of which 1,207,700 tons were classed as lump, 225,235 tons as nut, and 362 tons as smalls. The *South African Mining Journal* says that the collieries generally do not report the quantity of waste coal or slack. The coal hauled by districts was as follows :—Boksburg, 1,165,557 tons ; Heidelberg, 178,093 tons ; Middelburg, 69,164 tons ; Lydenburg, 23,422 ;

\* 9757 in original. † *Engineering and Mining Journal*, vol. lxi. p. 435.





four open-hearth furnaces, two acid and two basic of 12 tons capacity each, together with four puddling furnaces. The Duro Company, Asturias, works with three open-hearth furnaces, and 20 puddling furnaces, whilst the Mieres works possess one large open-hearth furnace.

**Iron Trade Statistics of Bilbao.**—The production of coal and coke in the Asturias has been as follows in the years mentioned :\*

	Coal.	Coke.
	Metric Tons.	Metric Tons.
1895 . . . . .	1,008,769	131,090
1896 . . . . .	1,122,700	150,000

The total production of coal in Spain amounted in 1895 to 1,739,075 tons, and in 1896 to 1,830,771 tons, but, with the exception of the production of Asturia, this additional output, on account of the transport costs, is of no importance to the port of Bilbao. There were imported into Bilbao the following quantities in the years named :—

From	1895.		1896.	
	Coal.	Coke.	Coal.	Coke.
	Tons.	Tons.	Tons.	Tons.
United Kingdom . . . . .	348,721	70,886	373,818	82,149
Germany . . . . .	100	7,839	...	17,152

The imports of coal and coke from Germany have gradually diminished, and since the past autumn have entirely ceased. The exports of iron ore from Bilbao have been as follows :—

To	1895.	1896.
	Tons.	Tons.
United Kingdom . . . . .	3,171,902	3,429,008
Netherlands . . . . .	609,619	805,176
France . . . . .	292,530	329,138
Belgium . . . . .	150,320	130,521
Germany . . . . .	3,243	5,229
United States . . . . .	17,128	45,432
Italy . . . . .	...	1,810
Totals . . . . .	4,244,742	4,746,314

\* *Deutsches Handels-Archiv*, July 1897.



**Exports.**—The Swedish statistics \* of exports during the first half of this year show a falling off in comparison with the corresponding period of last year. The exports included 24,290 tons of pig iron, 65,810 tons of wrought iron, 1193 tons of sheets, 3376 tons of heavy castings, and 999 tons of nails.

There has been an enormous increase in the recent exports of iron ore from Luleå. In 1896 the quantity exported amounted to 625,795 tons † as compared with only 384,007 tons in 1895. Of the total quantity exported, 448,315 tons were for Germany. The United Kingdom came next with 91,400 tons, and then Belgium with 62,350 tons, and France with 21,550 tons.

**Mineral Statistics of Norway.**—For purposes of comparison the mineral statistics are given. The latest mineral statistics for that country which have been published relate to the year 1895. They include 1250 tons of iron ore, and 494 tons of nickel ore.

XIX.—SWITZERLAND.

**Iron Trade Imports.**—The value of the imports into Switzerland have been as follows in the years stated, ‡ in millions of francs (1 million francs = £40,000) :—

	1885.	1892.	1896.
Coal . . . . .	17·6	33·2	46·7
Iron . . . . .	14·5	24·9	35·7

The imports of machinery have been as follows :—

Machinery for	1892.	1896.
	Value, Francs.	Value, Francs.
Spinning . . . . .	441,000	1,043,000
Weaving . . . . .	191,000	310,000
Sewing . . . . .	1,336,000	1,780,000
Tools . . . . .	515,000	1,050,000
Dynamos . . . . .	212,000	429,000
Electrical apparatus . . . . .	791,000	1,975,000

\* *Mining Journal*, vol. lxvii. p. 1176.      † *Deutsche Handels-Archiv*, August 1897.  
‡ *Stahl und Eisen*, vol. xvii. p. 836.



										Tons.
Virginia	.	.	.	.	.	.	.	.	.	2,018
Arkansas	.	.	.	.	.	.	.	.	.	3,421
Georgia	.	.	.	.	.	.	.	.	.	4,085
Other States	.	.	.	.	.	.	.	.	.	564
Total										10,088

**Petroleum Production.**—As regards the production of petroleum in 1896 in the United States, the principal features of the year are : the increase in production, which exceeds that of any previous year ; a general increase in the Appalachian oil field, especially in West Virginia ; a large increase of Lima oil in Ohio ; an increase in stocks and a decrease in prices. The total production for the year is given as 60,960,361 barrels, an increase of 15·25 per cent. over that of 1895. Previously the largest production was in 1891, when about 54½ million barrels were obtained. The Appalachian field is accountable for 55·7 per cent. of the total, the Lima-Indiana field for 41·4, and the remaining fields have only yielded 2·9 per cent. \*

The Bureau of Statistics reports that the exports of mineral oil from the United States during the half year ending June 30 amounted to 461,726,273 gallons.

**Tin-Plates.**—Colonel Ira Ayer† discusses the tin-plate industry in the United States. The industry dates its birth and the conditions which resulted in its rapid growth from the passage of the M’Kinley Tariff Act of October 1, 1890. The development of the industry is shown by the following statistics of production :—

	1892.	1896.
	Lbs.	Lbs.
Tin and terne plates . . . . .	13,646,719	307,228,621
Amount made from—		
American black plates . . . . .	9,296,553	303,002,098
Foreign black plates . . . . .	4,350,166	4,226,523

**Coal.**—The twenty-second annual report of the Chief Inspector of Mines of Ohio shows that the coal production of the State in 1896 amounted to 12,912,608 tons, a decrease of 771,271 tons as compared with 1895. There were 303 accidents during the year, including 41

\* *Eighteenth Annual Report of the United States Geological Survey.*  
† *Journal of the Franklin Institute*, vol. cxliv. pp. 424-446.



Country.	Year.	Production in Tons.
U . . . . .	1896	195,361,260
A . . . . .	1896	3,908,517
New Zealand . . . . .	1895	740,827
Queensland . . . . .	1896	377,350
South Australia . . . . .	1896	862
Tasmania . . . . .	1896	33,349
Victoria . . . . .	1896	226,562
Western Australia . . . . .	1896	9,801
Spain . . . . .	1895	9,722,679
Spain . . . . .	1896	18,389,147
Hungary, coal . . . . .	1895	1,068,046
" lignite . . . . .	1895	3,474,905
Belgium . . . . .	1896	21,252,370
Borneo . . . . .	1896	50,000
Canada . . . . .	1896	3,395,807
Cape Colony . . . . .	1896	107,050
France . . . . .	1896	29,310,832
Germany, coal . . . . .	1896	85,639,861
" lignite . . . . .	1896	26,797,880
Holland . . . . .	1896	137,787
India . . . . .	1896	3,848,013
Italy, lignite . . . . .	1896	276,197
Japan . . . . .	1896	3,000,000
Mexico . . . . .	1896	253,104
Natal . . . . .	1896	219,665
Peru . . . . .	1892	2,000
Portugal, anthracite . . . . .	1896	8,743
" lignite . . . . .	1896	8,000
Russia . . . . .	1896	9,009,000
Servia . . . . .	1894	120,000
South African Republic . . . . .	1896	1,471,189
Spain . . . . .	1896	1,852,947
Sweden . . . . .	1896	225,848
United States . . . . .	1896	171,416,390

A similar summary showing the production of pig iron is as follows :—

Country	Year.	Production in Tons.
United Kingdom . . . . .	1896	8,659,681
Austria . . . . .	1895	778,510
Hungary . . . . .	1895	349,163
Belgium . . . . .	1896	959,414
Canada . . . . .	1896	60,030
France . . . . .	1896	2,333,702
Germany . . . . .	1896	6,374,816
Italy . . . . .	1895	9,213
Japan . . . . .	1894	15,760
Russia . . . . .	1895	1,454,298
Spain . . . . .	1896	100,786
Sweden . . . . .	1896	494,418
United States . . . . .	1896	8,623,127





States is shown by the fact that, while in 1886 the production of Bessemer steel amounted to 2,305,497 tons, and that of open-hearth steel to 224,477 tons, in 1894 these out-turns were respectively 3,628,454 tons and 797,495 tons, and in 1895, 4,987,674 tons and 1,155,377 tons. It is estimated that in 1896 the production of open-hearth steel amounted to as much as 1,600,000 tons, or seven times as much as it was ten years previously. The production of Bessemer metal in 1896 was 3,982,624 tons. In the case of 233 open-hearths for which details are available, ten took a 50-ton charge, six 40 tons, eight 35 tons, twenty-five 30 tons, twenty-four 25 tons, fifty 20 tons, two 18 tons, forty-five 15 tons, fourteen 12 tons, and twenty-five 10 tons. Eighty per cent. of the total quantity of open-hearth metal made in the United States is produced in Pennsylvania. Other details relating to the production of rails, &c., are also given.

Turning next to the United Kingdom, the author gives statistics for the same period dealt with in the case of the other countries—1865 to 1896. The falling off in the manufacture of puddled iron is, he shows, extremely marked. In 1877 the number of existing puddling furnaces was 7159, whilst in 1895 only 3095 furnaces were in existence, and of these but 1775 were in operation. The production of Bessemer metal increased rapidly up to 1889, but since then there has been a diminution.

In 1896, 25·1 per cent. of the total production of Bessemer metal was made in basic-lined converters. Of the 101 existing converters in 1896, 23 were basic lined. In 1873, the out-turn of open-hearth metal was only 77,500 tons, but the increase in the production was subsequently so rapid, that in 1894 it exceeded the Bessemer out-turn; and in 1896, of the total ingots made, only 43·9 was made by the Bessemer process, whilst as much as 56·1 was made in the open-hearth. The basic open-hearth process, it is pointed out, is still relatively unimportant in the United Kingdom.

France is next dealt with briefly, and similar statistics are also given for this country, and also for the other countries previously mentioned. The author then proceeds to a general consideration of the state of the iron trade, and, dealing with the dephosphorisation process, he gives statistics showing the rise of this process in each country. No complete details are procurable since 1892, still such details as are obtainable show how rapid the progress has been. Thus in 1878 only 20 tons was made by this process, whilst in 1893, 3,638,556 tons was made, including the production in Belgium and in the United States, for



The share taken by each country was as follows :—

Country.	1870. Per Cent.	1896. Per Cent.
Great Britain . . . . .	50·5	29·0
United States . . . . .	14·3	29·0
Germany and Luxemburg . . . . .	11·8	21·5
France . . . . .	10·1	7·7
Russia . . . . .	3·3	5·0
Austria-Hungary . . . . .	2·5	3·2
Belgium . . . . .	5·0	3·0
Sweden . . . . .	2·5	1·6
Total . . . . .	100·0	100·0

**The Fuel Supply of the World.**—In the Mathematical Section of the British Association, Lord Kelvin gave an address on the fuel supply and air supply of the world. He quoted valuable statistics concerning the coal supply of the United Kingdom and its relation to the amount of oxygen in the atmosphere. The chief point of the address was that the amount of oxygen in the air was barely sufficient to consume the available fuel, and that mankind was more likely to suffer in time from lack of the former than of the latter. The chief necessity, therefore, was to see that by vegetation the supply of oxygen was constantly and adequately renewed. In the course of his address, Lord Kelvin incidentally expressed the belief that life had existed on the earth for twenty million years.

**Mine Accidents.**—According to *Glückauf*,\* the average annual number of fatal accidents in the years 1891 to 1895 per 1000 men employed in collieries was as follows :—

Country.	Total.	From Falls of Roof and Sides.
France . . . . .	1·099	0·400
Belgium . . . . .	1·664	0·544
Great Britain . . . . .	1·536	0·645
Prussia . . . . .	2·493	0·921

**The World's Railways.**—In the five years 1891–95, the length of the world's railways has increased by 62,465 kilometres (say 38,800 miles), an increase of 9·8 per cent. Of this increase only 22,104 kilometres was in Europe.† The total length of all the railways at the

\* Vol. xxxiii. p. 707.

† *Stahl und Eisen*, vol. xvii. pp. 543–545.

end of 1895 amounted to 698,356 kilometres—approximately 434,000 miles. This total was made up as follows :—

	Kilometres.
America . . . . .	369,686
Europe . . . . .	249,899
Asia . . . . .	43,279
Australia . . . . .	22,349
Africa . . . . .	13,143
Total . . . . .	698,356

Full details are given for each country and for each of the years 1891–95. The following are some of these :—

	Length in Kilometres.	
	1891.	1895.
United Kingdom . . . . .	32,487	33,648
Austria-Hungary . . . . .	28,066	30,046
France . . . . .	37,723	40,199
Germany . . . . .	43,424	46,413
Russia . . . . .	31,071	37,746

Bennett H. Brough \* states that although there were in Sweden, in 1856, not more than forty-one miles of railways for locomotives, at the present time no other country in Europe has so great a length of railway per inhabitant. This is shown in the following table, which, on the authority of the *Journal Officiel* of October 28, 1897, gives the number of miles of railway per 10,000 inhabitants on January 1, 1897 :—

	Miles.
Sweden . . . . .	12·5
Switzerland . . . . .	7·4
France . . . . .	6·6
Denmark . . . . .	6·1
Norway . . . . .	6·0
Germany . . . . .	5·6
Belgium . . . . .	5·6
United Kingdom . . . . .	5·4
Austria-Hungary . . . . .	4·5
Spain . . . . .	4·2
Holland and Luxemburg . . . . .	3·8
Roumania . . . . .	3·3
Italy . . . . .	3·0
Portugal . . . . .	2·8
Greece . . . . .	2·7
Russia . . . . .	2·3
Servia . . . . .	2·3
Turkey . . . . .	1·7

At the present time Sweden possesses 6154 miles of railway.

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